The Mesial Fins of Ganoids and Teleosts.

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(Plates XXI.–XXIII.)

I. INTRODUCTORY.

There seems to be a certain amount of obscurity in the ordinary text-book and other references to the structure and disposition of the supporting skeletal elements of the mesial fins of Ganoid and Teleostean Fishes. These structures are usually referred to as "interspinous bones or cartilages," and as a rule are described as elongated, dagger-shaped bones which at their inner extremities are intercalated between the vertebral neural or hæmal spines, and support distally the series of dermal fin-rays. It seems also to have been tacitly assumed, if not actually so stated, that in most instances each "interspinous" element is a simple unsegmented structure. Thus, Parker [1] in his paper on the skeleton of *Regalecus argenteus*, after referring to the presence of a series

of ovoidal nodules of cartilage in connexion with the distal extremities of the interspinous bones of the mesial fins of this fish, remarks (p. 24):—"I have not met with cartilages of this kind in any fish which has come under my notice, and I can find no account of any such in works at my disposal. I regard them as representing a second or distal series of radials or pterygophores, the interspinous bones forming the proximal series." That Parker was correct in his view of the nature of these cartilages there can be no doubt; and so far as I have been able to discover he appears to have been the first to recognize the existence of bisegmental "interspinous" elements in any Teleost. More recently it has been shown by Ryder [2] and Harrison [3], that in the development of the fins in those Teleosts which they examined each "interspinous" element consists of a proximal division to which is appended a distal nodule of cartilage for the immediate support of a dermal fin-ray, and hence, as in *Regalecus*, such elements are bisegmental. It is, however, by no means difficult to show that these cartilages, or their equivalents in the form of osseous nodules, are very generally present in Teleosts; and further, that in not a few families the intercalation of a hitherto unrecorded * series of mesial ossicles between the proximal and distal segments renders such "interspinous elements" trisegmental.

The main object of the present communication is to describe (*a*) the degree of segmentation and the more characteristic modifications of the "interspinous elements" of the dorsal and anal fins of Teleosts; (*b*) the extent to which such modifications are characteristic of particular groups or families; and (*c*) the various methods by which in different families the segments of the "interspinous" elements contribute to the support of the fin-rays. With these ideas in view a large number of Teleosts were examined, and as far as possible the species selected for examination are typical representatives of the leading subdivisions of the group. Although this paper was originally intended to deal exclusively with Teleosts, it has been thought desirable to include the Ganoids, and also to refer briefly to the Holocephala and Elasmobranchs, in order that an accurate comparison of the fin-supports in these four great groups of Fishes might be made.

The early stages in the development of the mesial fins of

* See reference to Günther's figure of *Beryx decadactylus*, p. 563.

certain Teleosts have been described by Ryder (*l. c.*), and recently in an admirable paper by Harrison (*l. c.*). The observations to be recorded here refer only to adult specimens, and hence may perhaps be regarded in the light of a sequel to the embryological work of these writers.

I have purposely omitted all reference to the supporting skeletal elements of the caudal fins, for the reason that these structures have already received considerable attention at the hands of Kölliker, Huxley, Emery, Lotz, Ryder, and others, to whose researches I have nothing to add.

With regard to the nomenclature to be applied to the so-called "interspinous" bones, and to the segments of which they are composed in different fishes, I must admit that I have experienced some difficulty in the selection of suitable terms. By different writers these structures have been described as "interspinous bones or cartilages," "interspinalia," "fin-bearers," "pterygophores." Ryder (*l. c.*) refers to the distal nodules of cartilage supporting the fin-rays as "actinophores," which, from their relation in the anal or dorsal fins to the hæmal or neural spines of contiguous vertebræ, become interhæmal (hypaxial), or interneural (epaxial) actinophores, the proximal divisions being spoken of as "interspinous elements." Dean [4] designates the two divisions of a bisegmental "interspinous bone" as "radials" and "basals"—the former term applying to the ordinary dagger-shaped interspinous elements, and the latter to the distal cartilaginous nodules or "actinophores" of Ryder*; while Parker (*l. c.*) has suggested the term "pterygophore" as applicable to "any radial or fin-supporting cartilage in either the median or paired fins." It is clearly desirable, in selecting appropriate terms for these structures, that they should be equally applicable to the supporting elements not only of the unpaired dorsal, anal, and caudal fins, but also to the homodynamous structures in the paired pectoral and pelvic fins; and from this point of view such terms as "interspinous bones," or "interspinalia," are obviously unsuitable. "Pterygophore" is a somewhat cumbersome term, especially when it is necessary, as is often the case, to indicate the segments of which a "pterygophore" is composed. "Radials" and "basals" are convenient terms when a fin-support is bisegmental, but scarcely so in the case of trisegmental structures.

* The terms "baseost" and "ἐxonost" have also been suggested (Cope, Am. Nat. 1890, p. 413).

I would suggest, therefore, the use of the term "*radial element*" as the unit of the series of skeletal fin-supporting bones, or cartilages, in both the mesial and paired fins; and in those instances in which such elements undergo segmentation, the terms *proximal*, *mesial*, or *distal segments* may be adopted.

The various species referred to in the descriptive section of this paper are those enumerated by Dr. Günther in the British Museum Catalogue of Fishes (1st ed.), and for this reason the authorities for the specific names have been omitted in the text.

In most instances in the description of the radial elements of different species the number of these elements has been given, but as these structures are liable to some slight individual variation in the same species, the number mentioned must be taken as applying only to the particular specimen examined.

II. DESCRIPTIVE.

ELASMOBRANCHII.

The dorsal and anal fins, but more particularly the dorsal fins, have been so fully and carefully described by Thacker [5] and Mivart [6], that it is unnecessary to do more than direct attention to a few of their results for the sake of comparison with other types. In the majority of the species described and figured by Mivart (*l. c.*) the radial elements are cartilaginous, rod-like structures, generally of fairly uniform thickness throughout their length, and usually divided into proximal, mesial, and distal segments. The individual segments vary in length, and, in different species, each may in turn become the longest. The various radial elements in each fin may afford mutual support to one another, and gain in strength, through their arrangement in close parallel relations throughout their entire length, but occasionally they may separate slightly from one another, either proximally or distally, or even at both extremities. In no instance is there any definite articulation between particular segments of contiguous radial elements. The central, or approximately central, radial elements in either fin are usually the longest, but almost invariably the most anterior and posterior of the series undergo a reduction in length and also lose one or more of their constituent segments.

From this general type of fin-structure the more important deviations in particular genera are brought about by (*a*) the more or less extensive longitudinal concrescence of the proximal

segments of the radial elements, or of both proximal and mesial; (*b*) the suppression by fusion or atrophy of particular segments, so that more or fewer of the elements become bisegmental instead of trisegmental; and (*c*) the apparently secondary subdivision of the distal segments.

The horny fibres which support the peripheral portions of the fins are several times more numerous than the supporting radial cartilages.

HOLOCEPHALA.

According to Mivart (*l. c.*), the second dorsal fin of *Callorhynchus antarcticus* is supported by a series of forty-one, not quite contiguous, simple and undivided radial elements, of which the anterior are the longest, the remainder gradually decreasing in length from before backwards.

In a skeleton of *Chimæra monstrosa* in the Mason College Zoological Museum there are about one hundred and two similarly simple elements in the relatively much longer posterior dorsal fin of this species. None of the cartilages are in apposition, all being separated to a greater or less extent, while at the same time they are connected and supported by the longitudinal fibrous septum separating the dorso-lateral muscles of opposite sides of the body. As is well-known, the radial elements of the anterior dorsal fin in both genera are greatly modified by concrescence and in other ways, for the support of the powerful spine.

GANOIDEI.

Acipenseridæ.

Acipenser sturio.

As might be expected, the fin-supports of this and the next species are essentially similar to those of the Elasmobranchs, except for their partial ossification.

Dorsal fin.—In *Acipenser* the dorsal fin is supported by a series of sixteen distally distinct radial elements, each of which, with the exception of the first two, consists of three segments, the proximal being the longest, while the distal is reduced to little more than a mere nodule. The first and second have apparently lost their distal segments. The longest radial element is the third, the first and second being somewhat shorter, while those behind the third gradually diminish in length to the two or three most posterior ones, which are by far the shortest of the series.

As a rule each element is of the same thickness throughout its length, or nearly so, and the proximal segments are never dagger-shaped. Concrescence is still evident in the fusion of the proximal segments of the first and second, the eleventh, twelfth, and thirteenth, and those of the fourteenth, fifteenth, and sixteenth, into a single basal segment in each case. The radial elements are but feebly ossified. The first, including the basal segment which it shares with the second, the last two, and the distal segments of all, are wholly cartilaginous, but, with these exceptions, the proximal and mesial segments are partially ossified. In all cases, however, ossification extends only to the formation of a thin crust of superficial bone round an axial core of unaltered cartilage, and leaves the extremities of the segments entirely free from ossific deposit. There is no definite method of articulation between the segments of contiguous elements, although, as in the Elasmobranchs, the latter afford one another mutual support by their parallel disposition, fairly close apposition, and fibrous connexion throughout the greater part of their length.

The characteristic horny fibres of the Elasmobranchs and Holocephala are here replaced by partially ossified, multiarticulate dermal rays, which, as in the higher Ganoids and in Teleosts, are bifurcate proximally and branched distally. The dermal rays still, however, retain traces of the characteristic arrangement of the horny fibres of the preceding groups, in the fact that their cleft proximal extremities embrace not only the distal but to some extent also the mesial segments of their supporting radial elements; and also in their greater number. Altogether there are about forty dermal rays, or approximately about two and a half as many as the radial elements which support them.

Anal fin.—This fin is very similar to the dorsal. There are, however, only ten radial elements, all of which are trisegmental. The second is slightly the longest of the series, those behind gradually decreasing in length from before backwards. The proximal segments of the first and second, and those of the third and fourth, coalesce to form a single basal segment in each case. As far as the particular segments which undergo partial ossification are concerned, the anal differs but little from the dorsal fin, but ossification is somewhat more complete, and to a greater extent replaces the primitive cartilage in the former than in the latter.

About twenty-five dermal rays are supported by the radial elements.

It may be remarked that the precise number of radial elements in the mesial fins and the extent of their concrescence are subject to variation in different individuals. In a much larger specimen (about 8 feet in length) the number of radial elements in the dorsal fin was the same as in the smaller one; but the proximal segments which had fused into single basal pieces were those of the first and second, the third and fourth, and the fifteenth and sixteenth. In the anal fin only the proximal segments of the third and fourth had fused. The figure of the dorsal fin of an *Acipenser* given by Thacker [5], and reproduced by Mivart [6], exhibits only fifteen radial elements, and those represented with fused proximal segments are the first and second, and the eighth and ninth, while the tenth and thirteenth inclusive, in addition to the first, are figured as wanting their distal segments. It is also evident, from a comparison of the two specimens referred to above, that the older the fish the more complete is the extent to which the proximal and mesial segments become ossified, and the less intimately are the various radial elements related to one another.

Polyodontidæ.

Polyodon folium.

The mesial fins of *Polyodon* are, in the main, very similar to those of *Acipenser*, but indications of increasing specialization, and of a gradual approximation to the higher Ganoids, in certain minor points are not wanting.

Dorsal fin.—The dorsal fin is supported by a series of twenty radial elements (Pl. XXI. fig. 1), of which the approximately central ones are the longest, and the most anterior and posterior the shortest. All of them are divided into proximal (*p.s.*), mesial (*m.s.*), and distal (*d.s.*) segments, except the first and the last, which are without distal segments. The proximal segment in each element is about the same length as the mesial, or only slightly exceeds it, and is now somewhat dagger-shaped, with a pointed inner extremity and a much thicker distal portion. The distal segments are mere cartilaginous nodules, forming by their close apposition a well-defined and continuous margin to the periphery of the fin-supports, and also exhibiting a tendency to alternate with the cartilaginous distal ends of the mesial segments. The connexion between the various radial elements is, perhaps, less intimate than in *Acipenser*; only along the centre of the series,

that is at or near the junctions of the proximal and mesial segments, and distally are the elements in actual contact or fairly close relations with one another. Concrescence is less marked and is evident only in the case of the proximal segments of the first and second, and those of the nineteenth and twentieth. With the exception of those belonging to the last radial element, and the mesial segment of the first, all the proximal and mesial segments are fairly well ossified. The inner portions of the proximal segments are entirely osseous, but towards the middle of the length of each segment a slender axial core of cartilage makes its appearance round which the bone forms a thick layer. From the centre outwards the bone gradually thins away, while the core of cartilage thickens and eventually forms the wholly cartilaginous distal extremity of the segment. The mesial segments are, for the most part, solid bone in the centre, but from this point in either direction an axial core of cartilage appears, and the superficial bones gradually thinning away leaves the two extremities of the segment entirely cartilaginous.

From 51 to 53 dermal rays are supported by the twenty radial elements, and, as in *Acipenser*, their deeply cleft proximal extremities embrace the distal, and partially also the mesial segments of the different elements.

Anal fin.—In this fin there are eighteen radial elements, all of which are trisegmental. The only indication of concrescence is the fusion of the proximal segments of the first and second elements. In other respects the anal fin is very similar to the dorsal. The number of dorsal rays is approximately forty-nine.

Amiidæ.

Amia calva.

Dorsal fin.—The long dorsal fin of this Ganoid is supported by a series of forty-nine radial elements, all of which are trisegmental with the exception of the first two, the fifth, and the last. The first element is represented only by its proximal segment, which at its distal extremity is tipped with cartilage and supports the first dermal ray. The proximal segment of the second supports a small nodule of cartilage which apparently represents a distal segment. The fifth has no proper proximal segment, and consists only of small cartilaginous mesial and distal segments supported by the proximal segment of the sixth. The forty-ninth, or last of the series of ray-bearing radial elements,

resembles the second *. In all the remaining trisegmental elements (Pl. XXI. fig. 2) the proximal segment (*p.s.*) is a somewhat dagger-shaped bone, slightly broader at its distal extremity where it is tipped with cartilage, but pointed and completely bony at its inner end; and, moreover, presents no trace of the characteristic lateral longitudinal ridges which in most Teleosts separate the elevator and depressor muscles of the fin-rays. The mesial segments (*m.s.*), on the other hand, are short, somewhat hour-glass-shaped bones with cartilaginous extremities, while the distal segments (*d.s.*) are invariably small cartilaginous nodules. The three segments of each complete radial element are in ligamentous connexion with one another, and also with the corresponding segments of contiguous elements.

In one important feature the radial elements of *Amia* differ greatly from those of *Polyodon*, *Acipenser*, and the Elasmobranchs, and resemble the corresponding structures in *Lepidosteus*, and in those Teleosts in which the trisegmental type of radial element exists. The proximal segments are widely separated from one another, and the only connexion between them is the median vertical sheet of fibrous tissue in which they are imbedded; but the mutual relations of the mesial and distal segments are nevertheless such that the various radial elements afford one another mutual support, and two of them contribute to the support of each dermal fin-ray. Thus, each mesial segment is inclined backwards at an angle with the proximal segment and its distal or hinder extremity articulates with, or at all events rests upon, the anterior margin of the distal extremity of the proximal segment of the next succeeding radial element, while each distal segment is in part supported by its own mesial segment and in part by the anterior or upper margin of the mesial segment of the next radial element. Hence, as each distal segment carries a soft fin-ray, it follows that the latter is supported partly by the distal segment of the radial element to which it normally belongs, and partly also, but indirectly, by the mesial segment of the next succeeding element. All the fin-rays are of the soft multiarticulate kind, and each is cleft basally for the reception of the distal segment of a radial element.

The numerical disproportion between the radial elements and

* Immediately behind the forty-ninth, and in close relation with it, there is a vestigial element, consisting of a proximal segment only and without a dermal ray.

the dermal fin-rays, which is so characteristic a feature in the lower types, is altogether wanting in *Amia*. In the latter fish the two are numerically identical, each of the forty-nine radial elements having only a single fin-ray, and this appears to be the typical relation of the two series of structures in all the higher Fishes.

Anal fin.—In the anal fin eleven radial elements support a corresponding number of soft fin-rays. The radial elements are very similar to those of the dorsal fin, both in structure and mutual relations. All are trisegmental except the first two, the first consisting only of a proximal segment, and the second, in addition, of a nodular cartilaginous distal segment. The mesial segments of the third and fourth, and those of the tenth and eleventh, and the distal segments of all the radial elements are cartilaginous.

It would seem that both the anal and dorsal fins are liable to individual variation as regards the precise number of their radial elements. In the specimen described and figured by Franque [7] there were apparently fifty-three elements, including the vestigial rayless one which, as in my specimens, lies immediately behind the last ray-supporting element, and fifty-three dermal fin-rays. The proximal segments of the first and second are figured as if fused together, which was certainly not the case in the specimens I have examined. Shufeldt [8] also mentions fifty-three as the number of radial elements in the specimens he examined. The anal fin is figured by Franque (*l. c.*) as having twelve radial elements, and this seems also to have been the case in Shufeldt's specimens.

It may be remarked that both Franque and Shufeldt overlooked the presence of the distal series of segments in both the anal and dorsal fins. The latter writer, for example, in referring to the fin-rays of the dorsal fin says, "These rays are supported by an equal number of interspinous bones, through the intervention of little ossicles that pass obliquely from one to the other" (*l. c.* p. 85). The "little ossicles" are the mesial segments, the so-called "interspinous bones" being the structures which I have termed proximal segments, but no reference is made to the series of distal segments. Franque (*l. c.*) also makes a similar omission, although he has quite correctly figured the shape and mutual relations of the proximal and mesial segments.

Shufeldt (*l. c.*) figures and describes five "delicate little

bones" which lie behind the radial elements of the dorsal fin and continue the series as far as the caudal fin, and had previously been overlooked by Franque. In one of two specimens I examined four such structures were present and in the other three, in the form of elongated but extremely slender ossicles. As to the nature of these structures, there can be no doubt that they are the persistent proximal segments of a series of vestigial radial elements, and indicate the primitive continuity of the dorsal and caudal fins. The discrepancy in numbers in the different specimens examined is probably due to the well-known variability of such vestigial structures, of which yet another instance may be mentioned. In Shufeldt's figure of these vestiges (*l. c.*, pl. ix. fig. 25) they are represented as without dermal rays, but, curiously enough, in one of my specimens the last two of the series were related distally to two small broadly V-shaped vestigial fin-rays, which were wholly imbedded in the subcutaneous connective tissue; in the second specimen no trace of these structures could be found.

Lepidosteidæ.

Lepidosteus osseus.

Dorsal fin.—In this Ganoid the dorsal fin is situated immediately anterior to the anal fin, and consists of eight radial elements (Pl. XXI. fig. 3), supporting eleven soft dermal fin-rays. The 2nd to the 8th inclusive are trisegmental, and in shape and in their relations to one another and to those of contiguous elements the different segments closely resemble those of *Amia*. The mesial segments, like the proximal, are all well ossified, with the exception of that belonging to the second radial element, which, as is also the case with all the distal segments, is cartilaginous. The first radial element (*r.e.*[1]) has a much larger proximal segment than any of the others, and the simple elongated nodule of cartilage which is attached to its distal extremity apparently represents a distal segment. Of the eleven fin-rays, the first three are supported by the distal segments of the first radial element, and the tenth and eleventh by the corresponding segment of the last element. The remaining fin-rays are each supported by a distal segment, precisely as in *Amia*.

The fact that the proximal segment of the first radial element is larger than any of the other proximal segments, and is related to three dermal rays, suggests the possibility of the fusion of certain of the anterior supporting elements of the fin.

The segment itself, however, exhibits no indication that its size is due to the union of originally distinct elements; and I am inclined to think that the fact that it happens to support two rays in addition to the one, viz. the third, which properly belongs to it, is simply due to the concentration of certain of the anterior fin-rays, which have apparently lost their radial elements during the partial atrophy of a primitively more extensive fin. Similar instances of this concentration of fin-rays, and the support of two or more of them by a single radial element, are to be noted in the last radial element of the dorsal fin of *Lepidosteus* and in the first and last of a large number of Teleosts.

Anal fin.—The anal fin lies immediately beneath the dorsal fin, and consists of nine radial elements and thirteen fin-rays. All the radial elements, including the first, are precisely similar to the corresponding structures in the dorsal fin, but the last, as well as the first, supports three fin-rays.

Polypteridæ.

Polypterus bichir.

Dorsal fin.—The anterior section of the dorsal fin is composed of fourteen * more or less distinct finlets, each of which consists of a stout spine and a posterior membranous portion supported by four soft multiarticulate rays which are attached by their proximal extremities to the upper half of the posterior margin of the spine. The more posterior finlets exhibit a tendency to fuse with one another through the gradual extension backwards of the membranous portion and its attachment to the basal portion of the spine of the succeeding finlet. The last spine, that is the fourteenth, is united by the membranous part of its finlet to the first of a series of eight stout, similarly united, slightly branched and multiarticulate fin-rays, which form the posterior section of the dorsal fin. The latter fringe the dorsal margin of the terminal portion of the tail, and are continuous behind with the similarly constituted infra-caudal rays. The fourteen finlet-spines

* The number of finlets, and consequently also the number of radial elements, is liable to individual variation (*cf.* Günther, Brit. Mus. Cat. of Fishes, vol. viii. pp. 327 & 517): hence the figures given above must be taken to apply only to the particular specimen examined, which was 15 inches in length. It is interesting to note that a somewhat similar individual variation has recently been recorded for the Notacanthid Teleosteans (Goode & Bean, Proc. U. S. Nat. Mus. vol. xvii. pp. 456–470).

(Pl. XXI. fig. 4, *sp.r.*)are supported by an equal number of simple, laterally-compressed, unsegmented, and widely separated radial elements (*r.e.*). The latter are somewhat slender, and the slightly thickened upper or distal extremity of each is tipped with cartilage and forms a globose condyle, which fits into a suitable socket in the expanded base of its finlet-spine. The radial elements supporting the multiarticulate posterior series of fin-rays (fig. 5) are similar to those supporting the finlets, except for their greater length and more cylindrical shape. They are also more concentrated, and, instead of articulating with their rays by a ball-and-socket joint, the cleft base of each ray simply embraces the cartilage-tipped distal end of its supporting radial element. Most of the anterior radial elements are very obliquely disposed, their inner extremities being directed forwards and only to a slight extent downwards, so that practically the arrangement of these elements is nearly horizontal. More posteriorly, where the finlets become replaced by a continuous dorsal fin, the radial elements gradually become less horizontal, and, while still remaining obliquely disposed, approximate more to the vertical and interdigitate with the neural spines of the subjacent vertebræ. All the radial elements are embedded in the median vertical fibrous septum separating the dorso-lateral musculature of opposite sides of the body, and by it are connected with one another.

Thin, somewhat triangular, cartilaginous laminæ (fig. 5, *x*) are attached to the posterior margins of more or fewer of the radial elements, near their outer or distal extremities. These laminæ first make their appearance on the ninth, and gradually increase in size to the fifteenth. From the fifteenth to the twenty-first they diminish in size and finally disappear, the last one or two elements exhibiting no trace of them. In the twelfth to the fourteenth elements, inclusive, the laminæ become more or less completely ossified. Whether osseous or cartilaginous, the laminæ project backwards from the various radial elements with which they are in ligamentous connexion into the fibrous septum separating the dorso-lateral musculatures. These structures can scarcely belong to the category of radial elements, and are probably mere chondrifications of the intermuscular septum, developed for the purpose of strengthening the points of origin of the powerful erector muscles of the spines and fin-rays. At any rate the erectores of each spine or fin-ray take origin not

only from the anterior surface of its supporting radial element, but also from opposite sides of the intermuscular septum in which the lamina of the next anterior element is developed, and thence run obliquely backwards to their insertion into the base of the spine or fin-ray as the case may be *.

It may be mentioned that Mivart [6] seems to have entirely misunderstood the nature of the fin-supports of *Polypterus*. In his description of the dorsal fin he says :—"This fin is supported by radials which give off on one side small secondary rays proceeding dorsad and postaxiad" (*l. c.* p. 458 ; also pl. lxxix. fig. 6). It is clear from the use of the term "radials," as well as from the accompanying figure, that Mivart is here describing the spines and soft rays of the series of finlets, and has entirely overlooked the true "radials," which are situated beneath and support the finlets. It is probable that this usually accurate morphologist only had access to an imperfectly prepared skeleton.

Anal fin.—The anal fin of *Polypterus* consists of six radial elements (fig. 6), of which the first (*r.e.*[1]) is a simple bony rod, slightly thickened and tipped with cartilage at its ventral end. The remainder are bisegmental, each consisting of a ventral segment (*v.st.*) similar to the simple segment of the first, and a slender styliform dorsal segment (*d.st.*). The segments of all the elements are well ossified, with the exception of the dorsal segment of the last one, which is cartilaginous. The distal extremities of the ventral segments are in close contact with one another so as to form a continuous, even if somewhat irregular, peripheral margin. The first five radial elements are situated in front of the first complete hæmal arch (*h.s.*), to the spine of which the sixth is attached by ligament.

Thirteen soft multiarticulate and slightly branched fin-rays are supported by the six radial elements, the ventral segments of the latter being embraced for a third of their length by the cleft rays. Each element, however, obviously contributes to the support of at least two fin-rays.

In older and larger specimens than that described above, the ventral divisions of the different radial elements are not merely larger and relatively more expanded towards their distal extremities, but the three anterior ones, which are longer than

* Ryder (2. Pl. v, fig. 2) gives a figure, "from Agassiz's 'Poissons Fossiles,' modified after Kölliker," in which these structures are described as "non-ray-bearing interspinous epural elements."

the others, are partially confluent proximally and distally, although separated centrally by large oval or elongated vacuities. The fin-supports of a specimen of this character are represented in a figure by Mivart (*l. c.* pl. lxxix. fig. 8), which is perfectly accurate so far as the ventral segments are concerned, although, curiously enough, the dorsal segments of the radial elements are neither represented in the figure nor referred to in the text.

TELEOSTEI.

Physostomi.

Osteoglossidæ.

Osteoglossum formosum.

Dorsal fin.—In a skeleton of this species in the Mason College Zoological Museum there are eighteen soft fin-rays and nineteen* radial elements in the dorsal fin. The penultimate radial element consists of a proximal and a distal segment, the latter supporting a fin-ray; the last has only a proximal segment, and is also without a fin-ray. All the remaining elements (Pl. XXI. fig. 7), including the first, are trisegmental, and each consists of a long and somewhat dagger-shaped slender proximal segment (*p.s.*); a much shorter, slender, and slightly hour-glass-shaped mesial segment (*m.s.*); and a rounded, nodular distal segment (*d.s.*). All the segments are completely ossified. The proximal segments exhibit no trace of the strong lateral longitudinal ridges which in most Teleosts separate the erector and depressor muscles of the fin-rays while providing surfaces for their origin. The articular interconnexions of the various radial elements for mutual support are very similar to those of *Amia* and *Lepidosteus*. The slightly enlarged distal extremity of each proximal segment is divided into an anterior and a posterior facet. The posterior facet articulates with the mesial segment, which is directed obliquely backwards and upwards, and in turn articulates with the distal segment, but the latter is also supported by the anterior facet of the proximal segment of the next succeeding radial element.

With the exception of the last, all the radial elements support fin-rays. The cleft proximal end of each ray (*f.r.*) embraces the distal segment of its proper supporting radial element, but from what has been said as to the articular relations of each

* Exclusive of a slender splint-like bone which is situated immediately anterior to the first of the fin-bearing series, and is apparently a vestigial radial element.

distal segment it is clear that two elements contribute to the support of each ray.

Anal fin.—The anal fin (fig. 8) is a facsimile of the dorsal fin except for an increase in the number of radial elements and fin-rays, there being twenty-six of the former and twenty-five of the latter.

Muræniдæ.

Conger conger.

Dorsal fin.—The extensive dorsal fin of this species resembles that of *Osteoglossum*, and is equally primitive. All the radial elements (Pl. XXI. fig. 9) are similar in character, and all are trisegmental. The mesial segments (*m.s.*) are well developed, and although firmly united at one extremity to the proximal segments (*p.s.*), are nevertheless separated from the latter by well-marked sutures. The relations and articulations of the various segments of a radial element to one another and to those of contiguous elements for mutual support are much the same as in *Osteoglossum*.

As in *Amia* and *Lepidosteus*, and as in most other Teleosts with trisegmental radial elements, an interossicular ligament (fig. 9, *int. lig.*) extends between and connects together the distal and mesial segments of successive radial elements.

The fin-rays, as usual, are bifid at the base for the purpose of clipping the distal radial segments by which they are supported. Each of the basal arms of a fin-ray (fig. 10 *f.r.*) is provided with a peg-like projection or tubercle on its inner surface, and the two tubercles of each ray fit into shallow pits or sockets on the lateral surfaces of the distal segment (fig. 10, *d.s.*; also fig. 9). This method of connexion between fin-rays and the distal segments of their supporting radial elements will in future be referred to as a "peg-and-socket" articulation.

Anal fin.—The radial elements are precisely similar to those of the dorsal fin.

Anguilla anguilla.

In so far as the fin-supports are concerned, this species closely resembles the preceding.

Esocidæ.

Esox lucius.

Dorsal fin.—This fin consists of about twenty-one soft fin-rays, supported by twenty radial elements (Pl. XXI. fig. 11). The

first radial element (*r.e.*[1]) consists only of a bony proximal segment which has the usual dagger-like shape, and, in addition to being slightly expanded, is tipped with a pad of cartilage at its distal extremity. In the second (*r.e.*[2]) the cartilaginous distal portion of the segment becomes slightly elongated upwards and backwards, and a distal segment is added. In the third and succeeding elements as far as the seventeenth, the distal cartilaginous epiphyses of the proximal segments (*p.s.*) gradually assume the proportions and relations of true mesial segments. In the sixth element (*r.e.*[6]) an ossific centre makes its appearance in the epiphyses, and, gradually enlarging in the succeeding elements, becomes in the eighth to the twelfth inclusive (*r.e.*[8]–*r.e.*[12]) a fairly well-developed hour-glass-shaped mesial segment (*m.s.*). From the twelfth to the fifteenth the ossified mesial segment becomes gradually smaller and finally disappears. Posterior to the seventeenth element the cartilaginous epiphyses of the remaining proximal segments fuse into a continuous strip of cartilage supporting dorsally the corresponding distal segments. All the radial elements, except the first, possess distal segments (*d.s.*), which from the fourth to the fifteenth are more or less completely ossified, but remain simple cartilaginous nodules in front of the fourth and posterior to the fifteenth. The relations of the distal segments to the mesial segments, and to the proximal segments of contiguous elements, are precisely the same as in *Osteoglossum*.

It is obvious, therefore, that the central radial elements of the dorsal fin of *Esox*—that is from the sixth to the fifteenth inclusive—are typically trisegmental, and that anterior and posterior to these the elements become bisegmental or unisegmental according as a distal segment is, or is not, present.

All the proximal segments, except those pertaining to the first two and the last five radial elements, have each of their lateral surfaces traversed by a more or less well-marked longitudinal ridge, which separates the elevator and depressor muscles of each fin-ray and serves for the partial origin of both.

Of the twenty-one fin-rays the third, like those succeeding it, is supported by the distal segment of its proper radial element (viz., the third), which is, as it were, clipped by the cleft base of the ray. The two anterior rays simply rest basally on the thickened cartilaginous extremities of the proximal segments of the first and second radial elements.

In a second specimen examined, twenty-two fin-rays were present, the first three in this case being supported by the proximal segments of the first two radial elements.

Anal fin.—This fin very closely resembles the dorsal fin. There are fewer radial elements and fin-rays, viz., eighteen and twenty respectively, but all the central fin-supports are tri-segmental.

Cyprinidæ.

Barbus vulgaris.

Dorsal fin.—In this Cyprinoid the dorsal fin consists of twelve fin-rays, supported by ten radial elements (Pl. XXI. fig. 12). Of the latter the fifth to the ninth ($r.e.^5$–$r.e.^9$) inclusive are the most complete, each consisting of proximal (*p.s.*), mesial (*m.s.*), and distal (*d.s.*) segments. Each proximal segment is a relatively large and somewhat dagger-shaped bone, which for a variable portion of its length articulates by its straight and almost parallel anterior and posterior margins with the corresponding edges of the proximal segments in front and behind, and is traversed on each of its lateral surfaces by a prominent longitudinal ridge. The distal end of the segment is greatly thickened, and provided anteriorly with three facets, one median and two lateral, and posteriorly with a fourth articular surface. The mesial segments are short thick ossicles, suturally united at one extremity to the posterior facet on the distal end of the corresponding proximal segment, and with the usual oblique inclination backwards to its articulation with the somewhat quadrate and much smaller distal segment. The distal segment, as well as the contiguous margin of the mesial segment, rest inferiorly on the median facet of the next succeeding proximal segment. The first to the fourth radial elements ($r.e.^1$–$r.e.^4$) inclusive lack separable mesial segments, but possess instead, at first a facet, and ultimately an upwardly and backwardly directed postero-superior process with a terminal articular surface for the distal segment. The tenth or last (*v.e.*) is a vestigial element, being represented by a proximal segment only.

Of the twelve fin-rays, the first four are spines of variable length, decreasing in size from behind forwards; the remainder are soft multiarticulate rays. The first three spines are carried by the laterally expanded distal end of the proximal segment of the first radial element. The fourth, or large defensive spine

(*d.s.*), is the proper fin-ray of the first radial element, but although its bifid base clips the distal segment of that element, it is mainly supported by the two laterally-placed facets on the hinder margin of the distal extremity of the second proximal segment. The twelfth fin-ray mainly is supported by the distal segment of the ninth radial element ($r.e.^9$). All the remaining fin-rays are supported by a corresponding number of radial elements, viz., by the second to the eighth inclusive. In most instances not only does the cleft base of the fin-ray clip the distal segment of its radial element but, in addition, articulates by two basal condyles with the two facets on the anterior margin of the distal end of the proximal segment of the next succeeding element.

As in some other Cyprinoids, there are two or three vestigial radial elements which are represented only by proximal segments in the form of small, thin, and somewhat irregularly shaped laminæ of bone, and are situated immediately anterior to the first ray-bearing element. The vestigial elements undoubtedly indicate the existence of a primitively longer dorsal fin than is present in the adult, and it is quite possible that they may represent the original fin-supports of those additional fin-rays which are supported by the first of the normal series of radial elements.

Anal fin.—This fin consists of seven radial elements and nine fin-rays, and, on the whole, is very similar to the dorsal fin (Pl. XXI. fig. 13). In the series of radial elements, the presence of a distinct mesial segment in addition to proximal and distal segments is restricted to the fourth, fifth, and sixth. In front of the fourth the elements are bisegmental, while the seventh has only a proximal segment. The first element supports two fin-rays in addition to partially supporting the third, which is its proper ray. The fin-ray of the last radial element is firmly attached to its predecessor, and is really supported by the distal segment of the penultimate element. All the remaining fin-rays are supported precisely as in the dorsal fin.

Cyprinus carpio.

Dorsal fin.—Except for its greater length and the consequent increase in the number of radial elements and fin-rays, which are twenty-two and twenty-five respectively, the dorsal fin of the Carp closely resembles that of the Barbel. The trisegmental radial elements are the third to the twenty-first inclusive, the

first and second having only proximal and distal segments, and the last a proximal segment. It is, perhaps, worth remarking that the distal segments of more or fewer of the anterior elements apparently ossify from two distinct lateral centres, which entirely replace the primitive cartilage but nevertheless leave a persistent longitudinal suture.

The fourth fin-ray, the defensive spine, is the ray which rightly belongs to the first radial element, although, as in *Barbus*, it is mainly supported by the two laterally situated facets on the adjacent extremity of the proximal segment of the second. The three short anterior fin-spines, also as in *Barbus*, are supported by the distal end of the proximal segment of the first radial element.

The articular relations of the segments of the same radial element to one another and to those of contiguous elements, as well as the relations of the fin-rays to both, are much the same as in the preceding species.

Anal fin.—In all essentials this fin resembles the dorsal fin. There are seven radial elements and nine fin-rays. Of the former three, viz., the fourth, fifth, and sixth, are trisegmental, those anterior to them being bisegmental, while the seventh has only a proximal segment. The serrated defensive spine is the third of the series of fin-rays, and, as in the dorsal fin, is the one pertaining to the first radial element.

Abramis brama.

Tinca tinca.

Both the Bream and the Tench are very similar to the preceding Cyprinoids in the character of their radial skeletal elements. In both the dorsal and anal fins all, except the most anterior and posterior, are trisegmental, the remainder being bisegmental or unisegmental.

The Bream is remarkable for possessing a series of about eight well-developed lamellar ossicles which are situated immediately anterior to the normal ray-bearing radial elements of the dorsal fin, and lie between the neural spines of the subjacent vertebræ. These ossicles are the proximal segments of the fin-supports of the atrophied anterior section of the dorsal fin.

SALMONIDÆ.

Coregonus pollan.

Dorsal fin.—In the rayed dorsal fin there are twelve radial elements, supporting thirteen fin-rays. Of the radial elements, six, viz. the sixth to the eleventh inclusive, are trisegmental. The suture between the mesial and proximal segments is occasionally somewhat difficult to detect, but sections taken through the line of junction readily prove its existence. The first two elements and the last consist of proximal segments only, and the third, fourth, and fifth of a distal segment in addition.

The first radial element supports two fin-rays, of which the second rightly belongs to that element. All the remaining elements are each related to a single ray, although, as in the preceding Teleosts, two elements contribute, directly or indirectly, to the support of each.

A series of fifteen slender bones is situated in front of the first of the ray-bearing radial elements, imbedded in the median fibrous sheet separating the dorso-lateral muscles of opposite sides of the body, and agreeing in number with the subjacent vertebræ. Anteriorly to these, and continuing the series to the posterior face of the skull, there are two thin lamelliform bony plates, of which the anterior is much the larger. The seventeen slender or lamelliform ossicles are the proximal elements of a series of vestigial radial elements, and may be taken as an indication of a primitive extension of the dorsal fin as far forwards as the head.

Anal fin.—Eleven radial elements and thirteen fin-rays are present. The third to the eleventh of the radial series inclusive are trisegmental, the first and last unisegmental, and the second bisegmental.

The third fin-ray is the one belonging to the first radial element, which therefore supports two rays in addition to its own proper ray.

SILURIDÆ.

Platystoma tigrinum.

Dorsal fin.—With the exception of certain minor differences, the dorsal fin of this Siluroid resembles that of *Amiurus catus* which has been described by McMurrich [9]. There are eight distinct radial elements and a corresponding number of fin-rays (Pl. XXI. fig. 14). The five posterior radial elements are fairly similar,

and each consists of a proximal (*p.s.*) and a distal (*d.s.*) segment. Each proximal segment is broad above, but becomes slender and tapering towards its inner extremity. For the upper half of its extent the segment suturally articulates with its fellows in front and behind by straight or slightly curved anterior and posterior margins, while the distal extremity is somewhat expanded laterally and, at the same time, produced obliquely upwards and backwards into an abruptly truncated "postero-superior" process (*ps.p.*) which articulates with the distal segment, and almost precisely resembles a confluent mesial segment both in its relations to the distal segment and in its mode of articulation with the antero-superior margin of the next succeeding proximal segment. The postero-superior process and the adjacent anterior portion of the distal end of the segment furnish a smooth concave surface for articulation with the base of a fin-ray. The distal extremity of the proximal segment of the last radial element is produced backwards into a thick lamina of bone, which may possibly represent one or more fused segments.

The distal segments are simple osseous nodules. Interossicular ligaments extend from the upper surface of the postero-superior process of each proximal segment to the distal segment, and from the latter to the postero-superior process of the next succeeding proximal segment.

The first three radial elements (*r.e.*^{1}–*r.e.*^{3}) differ somewhat from the others. They are more or less firmly united together by suture throughout their entire length, and are otherwise modified for the support of the large defensive spine and the smaller spine in front of it—the "guard-spine"—which provides for the support and fixation of the defensive spine in the erect position. The first (*r.e.*^{1}) includes only a proximal segment (*p.s.*), and is represented by a somewhat triangular bony plate with the apex directed forwards and its base firmly attached by suture to the proximal segment of the second. Distally, the plate is produced outwards into two prominent lateral ridges. The second also consists only of a proximal segment (*r.e.*^{1}, *p.s.*) similar in shape to those which succeed it, but terminating distally in a projecting process (*p.*), provided with a smooth anterior surface, for the support of the "guard-spine" (*g.sp.*). Distally also, but at a point anterior to the projecting process already mentioned, the lateral margins of the segment are produced outwards and backwards in such a way as to form a horizontally disposed V-shaped

lamina of bone (Pl. XXI. fig. 15, *r.e.*^{2}, *p.s.*), in the angle of which is situated the "guard-spine," while the apex is suturally articulated with the produced lateral margins of the first proximal segment (*r.e.*^{1}, *p s.*). The third radial element (fig. 14, *r.e.*^{3}) is more normal, and consists of a proximal segment (*p.s.*) with a postero-superior process and an ossified cubical distal segment (*d.s.*) embraced by the cleft base of the third fin-ray. The proximal segment, like those of the preceding radial elements, has the lateral margins of its distal extremity produced outwards in the form of wing-like laminæ (fig. 15, *r.e.*^{3}, *p.s.*), which, superiorly, form a transversely elongated surface for the support of the defensive spine (fig. 14, *d.sp.*), and at either extremity suturally articulate with the hinder ends of the V-shaped lamina of the second proximal segment (fig. 15). The arrangement of the foramina for the transmission of the erector muscles of the guard and defensive spines is very similar to that described by McMurrich in the case of *Amiurus catus*. In a dorsal view (fig. 15) it will be seen that the V-shaped lamina, in conjunction with the lateral wings of the third proximal segment, encloses a somewhat triangular space in which are situated the bases of the two spines and their supports. The large foramen on each side of these structures (f^2) transmits the erector muscles of the defensive spine, the corresponding muscles of the "guard-spine" passing from their origin to their insertion through two much smaller lateral foramina (f^1) which perforate the distal end of the second proximal segment immediately beneath the V-shaped lamina.

There are eight fin-rays, which in order from before backwards include (i.) the "guard-spine," (ii.) the large defensive spine, and (iii.) a series of six soft multiarticulate rays. The third to the eighth inclusive, that is the six soft rays, are perfectly normal in their mode of support and in their relations to the last six of the radial series. Each ray (fig. 14) is supported partly by the distal segment of its proper radial element and partly also—and this is more particularly the case with the third, fourth, and sixth rays—by the articulation of its bifid condylar base with the distal extremity of the next succeeding proximal segment. The guard and defensive spines, however, are somewhat peculiar. The defensive spine, instead of being bifid, has a transversely elongated base, divided into a median and two lateral condyles, and apparently formed by the secondary fusion of the basal extremities of an ordinary cleft ray. The lateral condyles articulate with

the lateral wings at the distal end of the third proximal segment, immediately anterior to the origin of its postero-superior process, while the median condyle fits into a mesial pit. Above the three condyles, the base of the spine is perforated by an oval foramen through which is prolonged a curious hook-shaped process (*h*) developed from the anterior or dorsal surface of the postero-superior process, and from the extremity of the hook a stout ligament extends to an insertion into the distal end of the second proximal segment. This hook probably owes its formation to the partial ossification of the strong interossicular ligament which, in the absence of distal segments, passes between the distal extremities of the proximal segments of the first two radial elements, and in other Siluroids, where the ligament is completely ossified, gives rise to the characteristic "chain-link" articulation of the defensive spine with its supporting radial element. As the third radial element is already provided with a fin-ray, viz. the first soft ray, the defensive spine must be regarded as the ray normally pertaining to the second element. The "guard-spine" is a simple, short, V-shaped ossicle and, although supported by the second radial element, is really the fin-ray of the first.

This view of the relations of the anterior fin-rays to their supporting radial elements differs from that given by McMurrich in the case of *Amiurus* in one or two particulars. According to this writer the radial element of the defensive spine is the third, that of the "guard-spine" being the second, while the fin-ray of the first element is represented by the V-shaped lamina. The reason assigned for the last suggestion is—that what corresponds to the V-shaped lamina in *Amiurus* is an ossification in membrane, and ought therefore to be regarded as belonging to the category of fin-rays, inasmuch as the radial elements are always preformed in cartilage. In my opinion this reason is scarcely a conclusive one. The lateral wings of the third proximal segment in *Platystoma* are almost certainly formed of membrane-bone, and the same is in all probability true of the produced lateral margins of the first; but these facts alone are quite insufficient to justify one in regarding such outgrowths as degenerate fin-rays. Moreover, it is admitted by McMurrich that portions of the first and third "interspinalia" in *Amiurus* are formed of membrane-bone, and yet it is not suggested that such portions represent fin-rays. It seems more reasonable to infer that the partial ossification of certain proximal segments from membrane is the result

of the expansion of their distal extremities for the support of the modified defensive and guard spines. It may further be pointed out that, if the relations of the various radial elements to the series of fin-rays be traced from behind forwards, no special difficulty with regard to the mutual relations of the more anterior of them need be experienced. It is only necessary to bear in mind (i.) that in the normal portion of the fin each fin-ray is supported by two contiguous radial elements, although it is to the anterior of the two that the ray rightly belongs; and (ii.) that in the anterior portion of the fin the loss of the distal segments of their proper radial elements has led to the backward displacement of certain of the fin-rays (that is, the guard and defensive spines), and also to their exclusive support by the proximal segments of the radial elements immediately posterior to those to which they really belong. In the light of these considerations, it is an easy matter in the case of *Platystoma* to correlate the eight radial elements with the eight fin-rays in the order of their sequence from before backwards.

Anal fin.—In the anal fin there are thirteen radial elements and sixteen fin-rays. The fourth to the thirteenth radial elements (fig. 16) inclusive are composed of both proximal (*p.s.*) and distal (*d.s.*) segments, but without any trace of separable mesial segments. Each proximal segment is produced downward and backward into a postero-inferior process (*pi.p*), precisely analogous to the postero-superior processes of the dorsal fin, and, like the latter, having the appearance and relations of a confluent mesial segment. Each of the first three radial elements consists of a proximal segment only, which has no trace of the postero-inferior process of the succeeding segments. Concentration of the fin-rays is apparent at each extremity of the series. The last radial element supports two rays, while the first three support between them the first five fin-rays, of which the third is the normal ray of the first radial element. All the fin-rays have cleft bases and, with the exception of the first five, their mode of support is similar to that of the central and posterior rays of the dorsal fin. In the absence of distal segments, the first five rays are supported by the three anterior proximal segments.

Amiurus catus.

Dorsal fin.—This fin is very similar to the corresponding fin in the preceding species, and for an account of its structure and

development reference may be made to McMurrich's description of the osteology of *Amiurus* (l. c.).

Anal fin.—The anal fin is also very similar to that of *Platystoma* except for the greater number of radial elements and fin-rays, which in the specimen examined were twenty-one and twenty-two respectively.

Cnidoglanis megastoma.

In this Siluroid there are two dorsal fins, an anterior situated immediately behind the head, and a long posterior which is co-extensive with the caudal section of the trunk and continuous posteriorly with the caudal fin.

Anterior dorsal fin.—This fin is very similar to the dorsal fin of *Amiurus* and *Platystoma*, except that there are but six radial elements and seven fin-rays. The first three radial elements are precisely similar to those of *Platystoma*, both in structure and in their relations to the guard and defensive spines, the reduction in the number of radial elements being at the expense of the hinder of the series. The distal segment of the last radial element supports two dermal rays.

Posterior dorsal fin.—The posterior section of the dorsal fin is supported by a series of slender fin-rays, all of which are deeply cleft proximally and slightly branched distally. The proximal ends of the rays are pointed, and penetrate between the neural spines of the subjacent vertebræ into the median fibrous septum which separates the dorsal muscles of the trunk. Proximally also the rays are in ligamentous connexion with one another and with the extremities of the neural spines. There is no trace of radial elements in any part of the fin. With the possible exception of a few other Siluroids, the presence of fin-rays without supporting radial elements is a condition which is unique among Teleostean Fishes; and I am inclined to regard the total suppression of such elements as a transitional stage in the degeneration of the posterior dorsal fin to a vestigial adipose fin.

Anal fin.—In external appearance the anal fin is extremely similar to the posterior dorsal fin, but structurally the two are very different. A complete series of radial elements is present, in number about sixty-three or sixty-four, and, with the exception of the first, all are bisegmental, consisting of slender, distally expanded proximal segments and small nodular distal segments. The fin-rays and their mode of support are also perfectly normal.

There are indications of the concentration of fin-rays at the anterior end of the fin in the presence of two rays in excess of the number of radial elements.

Characinidæ.

Citharinus Geoffroyi.

Dorsal fin.—There are sixteen radial elements supporting nineteen dermal fin-rays. The radial elements (Pl. XXI. fig. 17) are all bisegmental, consisting of proximal (*p.s*) and distal (*d.s.*) segments, with no trace of mesial segments or of the postero-superior processes which so often take their place. The distal segments are somewhat interesting inasmuch as they illustrate a further stage in the gradual conversion of the segment into the hook-shaped distal segment of many Acanthopterygian Teleosts. The distal segment of the first radial element (*r.e.*[1], *d.s.*) is larger than any of the others, and in the form of an elongated and somewhat quadrate ossicle articulates with the distal end of its proximal segment (*p.s.*), and also partially overlaps the corresponding extremity of the next proximal segment and suturally articulates with its distal segment. The remaining distal segments are somewhat smaller, and many of them exhibit traces of a median longitudinal suture, but all of them have similar relations to their own and succeeding proximal segments as well as to contiguous distal segments. Excluding the first, each distal segment has on its lateral surfaces, near the anterior end of the segment, a concavity so deep that the two nearly meet in the centre of the segment (fig. 17). These concavities or sockets are for the reception of the condylar projections from the inner surfaces of the cleft basal end of a fin-ray (see dorsal view, fig. 18), and hence the mode of articulation of the two structures assumes a further extension of the "peg-and-socket" joint already indicated in the case of *Conger*. A slight extension of this modification in the direction of extending the inward growth of the two condylar projections of the fin-ray so that they meet and fuse, while at the same time the posterior end of each distal segment becomes contracted and curved into a hook, and the characteristic "chain-link" articulation of so many Acanthopterygii is easily reached. The distal segment of the first radial element differs from the rest in having three pairs of lateral sockets, the last pair, however, being in part formed by the hinder portion of

the corresponding segment of the second radial element. The first radial element is related to four fin-rays, of which the first three are but feebly developed. The first ray simply rests on the anterior margin of the distal end of the proximal segment; but the second, third, and fourth, the last mentioned being the ray strictly belonging to the first radial element, articulate with the three pairs of sockets on the distal segment.

Anterior to the first ray-supporting radial element there are seven flattened lamellar bones extending forwards nearly to the supraoccipital spine, and apparently representing a series of vestigial proximal radial segments which have lost their fin-rays.

Anal fin.—This fin in all essentials very closely resembles the dorsal fin, except for the larger number of radial elements (viz., twenty-five) and fin-rays (viz., twenty-eight). This distal segment of the first radial element is, however, apparently double.

Clupeidæ.

Clupea harengus.

Dorsal fin.—In this species the eighteen fin-rays of the dorsal fin are supported by a corresponding number of radial elements. All the radial elements are very similar, and each consists of a proximal and a distal segment, the former having a well-marked postero-superior process. No distinct mesial segments could be detected. The nodular distal segments are simply clipped by the cleft bases of the various dermal rays. In front of the first ray-bearing radial element there is a series of about eighteen slender vestigial proximal segments extending forwards at regular intervals to the skull.

Anal fin.—There are fifteen radial elements, all of which are very similar to those of the dorsal fin, and seventeen fin-rays. The first radial element supports two fin-rays, of which the second clips the distal segment. The last radial element is also related to two fin-rays supported by its distal segment.

Gymnotidæ.

Gymnotus electricus.

The dorsal fin is entirely absent.

Anal fin.—The long anal fin of this species is supported by an equally extensive series of radial elements. The latter (Pl. XXII.

fig. 19) consist of long, slender, rod-like proximal segments (*p.s.*), each of which is slightly expanded and tipped with cartilage at its distal end. There is no trace of mesial segments, or of postero-superior processes to the proximal segments, and a series of fibrous pads, interposed between the proximal segments and the fin-rays, are all that represent the osseous or cartilaginous distal segments of other Fishes. The radial elements have no articular connexion with one another, and, except for a continuous ligamentous connexion between the distal extremities of their proximal segments, are quite distinct.

The fin-rays (*f.r*) correspond in number with their supporting radial elements, and each is supported solely by a single element. Their cleft basal extremities, which have irregular dentate edges instead of smooth articular surfaces as in most other Teleosts, embrace between them the fibrous representatives of the distal radial segments.

Anacanthini.

Gadidæ.

Gadus æglefinus.

In this Gadoid there are three dorsal fins—an anterior, a mesial, and a posterior, separated from one another by short but distinct intervals. The anal fin is also divided into similarly separated anterior and posterior divisions.

Anterior dorsal fin.—Sixteen radial elements form the supporting skeleton of this section of the dorsal fin. All but the last consist of a large well-ossified proximal segment with a well-developed postero-superior process, and a small, cartilaginous, nodular distal segment, which is embraced by the cleft base of its dermal fin-ray. The last of the series consists of a small proximal segment only, without a distal segment or a fin-ray.

Mesial dorsal fin.—This fin is very similar to the anterior dorsal but includes nineteen radial elements, each, including the last, consisting of proximal and distal segments and supporting a fin-ray.

Posterior dorsal fin.—The posterior division of the dorsal fin very closely resembles the mesial section. There are, however, twenty radial elements and a corresponding number of fin-rays.

It may be noted that in each section of the dorsal fin the fin-

supports gradually diminish in size from before backwards, and the same may be said of the three sections collectively.

Three vestigial radial elements, without distal segments or fin-rays, are interposed between the mesial and porterior dorsal fins. It may in fact be said that, so far as their radial elements are concerned, these fins form a continuous structure, the interval between them which is apparent externally being simply due to the suppression of the three fin-rays corresponding to the three vestigial radial elements.

No vestigial elements between the anterior and mesial dorsal fins could be detected.

Anterior anal fin.—This section of the anal fin consists of twenty-five radial elements and twenty-six fin-rays. Of the former, all but the last are bisegmental, and in other respects are very similar to the corresponding structures of the dorsal fin. The last of the series is much smaller than the rest, almost horizontal in position, and, in the absence of a distal segment, its cartilaginous extremity supports a feebly developed ray. In addition to its own proper ray, the second of the series, the first radial element supports a feeble ray in front of the former.

Posterior anal fin.—In this fin there are twenty radial elements and an equal number of fin-rays. All but the last, which lacks a distal segment, are bisegmental.

As in the case of the mesial and posterior dorsal fins, the interval between the anterior and posterior anal fins is occupied by three vestigial radial elements which complete the continuity of the two series.

Gadus morrhua and *Merluccius vulgaris.*

In both these Gadoids the radial elements are essentially similar to those of the preceding species.

Pleuronectidæ.

Pleuronectes platessa.

Dorsal fin.—The continuous dorsal fin not only extends nearly the whole length of the body but also on to the posterior three-fourths of the head. The supporting radial elements (Pl. XXII. fig. 20), including those on the head, are all bisegmental. The proximal segments (*p.s.*) are long, relatively narrow, vertically disposed structures. Distally, each segment terminates in a

cartilage-tipped extremity, provided with two flat oblique surfaces meeting at an angle. The distal segments (*d.s.*) are all cartilaginous, somewhat plano-convex in shape, and intercalated between the distal ends of the proximal segments in such a way that the convex inferior surface of each articulates with two oblique surfaces furnished by the distal extremities of two contiguous proximal segments. Towards the anterior and posterior extremities of the fin, the distal segments to some extent lose their usual intercalated arrangement and become more directly related to the distal ends of the proximal segments to which they belong.

All the fin-rays are cleft basally and clip the distal segments of their supporting radial elements.

Anal fin.—In the structure and disposition of its radial elements the long anal fin closely resembles the dorsal.

Acanthopterygii.

Berycidæ.

Holocentrum spiniferosum.

Dorsal fin.—The dorsal fin consists of an anterior spinose portion and a posterior section consisting of soft multiarticulate fin-rays. There is, however, no interruption in the sequence of either the fin-rays or the supporting radial elements. Twenty-five radial elements (Pl. XXII. fig. 21, $r.e.^{1}$–$r.e.^{25}$) are present, of which the first ten support eleven stout spines, the remaining fifteen supporting sixteen soft rays. The ten spine-bearing elements ($r.e.^{1}$–$r.e.^{10}$) are bisegmental, each consisting of a dagger-shaped proximal segment (*p.s.*) with well-marked lateral longitudinal ridges, and, in addition, a distal segment (*d.s.*). Each proximal segment has at its distal end (i.) an anterior facet for articulation with the distal segment of the radial element immediately anterior to it; and (ii.) behind the facet a transversely disposed articular surface for the condylar base of a fin-ray. Posteriorly to this the distal end of the segment contracts somewhat, and then widens out into two transversely disposed lateral wings (fig. 22, *p.s.*) which are directed upwards as well as outwards, and, in conjunction with similar wings developed from the distal segment (*d.s.*), form a section of a well-marked medio-dorsal bony groove extending the whole length of the spinose portion of the fin, and serving for the reception of the spines when the latter are deflected. The lateral notches (*n*) which are to be seen

between successive sections of the osseous groove serve for the transmission of the elevator and depressor muscles of the spines. Each distal segment (Pl. XXII. figs. 21, 22, *d.s.*) suturally articulates with the hinder margin of the distal end of the corresponding proximal segment, and consists of (*a*) a central nodular portion, (*b*) the lateral wings already mentioned, and (*c*) a hook-shaped prolongation (*h*) from the centre of its hinder margin, which, after curving backwards and a little downwards, becomes firmly connected by ligament with an osseous tubercle (*t*) on the adjacent distal end of the proximal segment of the next succeeding radial element in such a way that the hook and tubercle together form a bony link or loop. Posteriorly, the distal segment articulates with the anterior of the two facets with which the distal end of the next succeeding proximal segment is furnished.

The spinose fin-rays have much the same structure throughout the series. In each case the base of the spine forms a transversely elongated condyle for articulation with a similar facet on the distal end of the proximal radial segment, immediately behind that to which it rightly belongs; while above the condyle the base of the spine is perforated by a foramen, through which passes the bony hook formed by the distal segment of its proper radial element, that is, the next anterior element.

The evolution of this method of articulation between a distal radial segment and a fin-ray is, I believe, an extreme modification of the "peg-and-socket" articulation, the first appearance of which was noted in the *Conger* and a later stage in *Citharinus*. The ingrowths from the inner surfaces of the originally cleft base of a fin-ray have now met and fused, forming a transverse basal condyle for articulation with a proximal radial segment, but above the condyle there is left a foramen through which passes the now contracted and hook-like posterior portion of the distal segment. This mode of articulation is extremely characteristic of many Acanthopterygian Teleosts, and in future will be referred to as a "chain-link," although I may so far anticipate the sequel as to say that "chain-link" articulations may be formed by various methods in different Teleosts.

The first radial element (Pl. XXII. fig. 21, *r.e.*[1]) supports two spines, of which the first has a chain-link articulation with the distal extremity of the proximal segment, while the second spine, the proper ray to this element, has the normal "chain-link" connexion with the distal segment. It is somewhat difficult to account for

the mode of articulation of the first spine; but I am inclined to think that the chain-link in this case is due to a modification similar to that by which the same kind of articulation is brought about in the case of the distal segments and spines of the rest of the fin, viz., by the ingrowth of the basal extremities of an ordinary cleft ray through the distal end of a *proximal* segment.

There is a striking contrast between the radial elements already described and the fifteen ($r.e.^{11}$–$r.e.^{25}$) supporting the sixteen soft rays of the hinder section of the dorsal fin. The elements are all trisegmental, consisting of proximal (*p.s.*), mesial (*m.s.*), and distal (*d.s.*) segments, which have almost precisely similar relations to one another, and to those of contiguous elements, as in the Cyprinidæ and other Teleosts with trisegmental radial elements. Behind the fifteenth there is a vestigial proximal segment (*v.e.*) suturally united to the one in front.

Each fin-ray is cleft basally and clips the distal segment of its proper radial element, although, as usual, the ray is partly supported by the next succeeding proximal segment. The distal segment of the last element contributes to the support of two rays.

Immediately anterior to the first radial element of the dorsal fin there are two vestigial elements without rays.

Anal fin.—There are twelve radial elements (fig. 23) and fifteen fin-rays, and, of the latter, four are spinose and the remainder soft and multiarticulate.

The third to the twelfth radial elements inclusive ($r.e.^{3}$–$r.e.^{12}$) are trisegmental and in every respect similar to those in the hinder section of the dorsal fin, but the first and second ($r.e.^{1}$–$r.e.^{2}$) have only proximal and distal segments (*p.s.*, *d.s.*). The proximal segments of the first two elements are exceptionally long and stout, and are firmly, but suturally, united together; the remainder are slender and gradually decrease in size as they extend backwards. The distal segment of the third radial element is a simple cubical ossicle similar to those of the succeeding elements; but those of the first and second consist of a cubical body produced distally into anterior and posterior hook-like processes, of which the anterior is simply due to the ossification of the interossicular ligament in continuity with the segment itself. The proximal and distal segments of the first two radial elements furnish either peg-and-socket or chain-link articulations for the first four spinose fin-rays. A tubercle on

the anterior margin of the distal end of the first proximal segment has two lateral pits for the first spine, which therefore has a "peg-and-socket" articulation with that segment. Behind these lateral pits there is a bony loop formed anteriorly by a process of the same segment, and behind by the anterior limb of the distal segment and furnishing a chain-link articulation for the second spine. Posteriorly to this a second ring is formed, partly by the hook-like posterior limb of the same distal segment and completed by the ossified interossicular ligament which extends from the extremity of the hook backwards to the distal extremity of the second proximal segment this bony loop has a chain-link connexion with the third and largest of the spinose rays. Finally, the hooked distal segment of the second element in conjunction with the mesial segment of the third forms a third bony ring for a similar articulation with the fourth and last spinose ray. A comparison of these spines and their relations to their fin-supports renders it clear that the third spine is that rightly belonging to the first radial element, and that the first and second have lost their normal fin-supports and acquired a secondary connexion with the first persistent, ray-bearing element.

All the soft rays are basally cleft and simply clip the distal segments of their supporting radial elements. The last element, however, supports two feebly developed rays.

Beryx decadactylus, Cuv. & Val.

In a figure of the skeleton of this species by Günther (9 *a*, pl. vi.) more or fewer of the radial elements in the soft-rayed portions of the dorsal and anal fins are represented as trisegmental. The sutures between the proximal and mesial segments are somewhat indistinct in the dorsal fin, but are quite obvious in the anal fin. This is the only instance of which I am aware in which the trisegmental character of the radial elements of a Teleost has been previously recognized. It must be pointed out, however, that Günther gives no description of the radial elements, nor does he in any way refer in the text to their segmentation.

Three vestigial elements, consisting of proximal segments only, are figured in front of the first ray-bearing element of the dorsal fin.

Percidæ.

Perca fluviatilis.

Except for the absence of mesial segments, the fins and fin-supports of this species have a fairly close resemblance to those of *Holocentrum*.

Anterior Dorsal fin.—This fin consists of fifteen spinose rays supported by a like number of radial elements. All the radial elements are bisegmental except the last three, which have proximal segments only. Most of the proximal segments have well marked postero-superior processes which appear to take the place of the missing mesial segments. As in *Holocentrum*, all the distal segments are provided with hook-like processes. The distal segment of the first element seems, however, to have fused with the proximal segment, a groove at its base alone indicating its original distinctness.

A median dorsal bony groove for the reception of the deflected spines is present in *Perca*, but the successive sections are formed by lateral wings developed from the postero-superior processes of the proximal segments, in conjunction with those contributed by the distal segments.

The first spine has a "chain-link" articulation with the distal end of the first proximal segment. The second, a similar articulation with the corresponding distal segment, and, in addition, a basal articulation with a transversely elongated articular surface on the distal extremity of the second proximal segment. The remaining spines have precisely similar articulations, two successive elements contributing to the support of each spine. The last three radial elements being without distal segments, it follows that the last and penultimate spines, which are very feebly developed, and rightly belong to the thirteenth and fourteenth elements, are supported solely by the fourteenth and fifteenth proximal segments respectively. The first two of these spines have simple cleft basal ends, without articular surfaces, and merely clip the dorsal extremities of their fin-supports; the third is a simple undivided ray, and is supported by fitting into a cleft in the distal extremity of the last proximal segment.

Anterior to the first ray-bearing radial element there is a vestigial proximal segment which is probably the normal fin-support to the first spine.

Posterior Dorsal fin.—In this fin there are fifteen radial elements all of which consist of a proximal segment, with a well-marked postero-superior process, and a simple cubical distal segment, with no trace of a hooked process. The fifteen fin-rays are all soft and multiarticulate, and their cleft basal extremities simply embrace the distal segments.

Anal fin.—In this fin there are nine radial elements and eleven fin-rays, of which two are spinose and the remainder soft. With the possible exception of the first, all the radial elements are bisegmental, and similar, both in structure and in their mode of articulation with the fin-rays, to those of the posterior dorsal fin. All the proximal segments, except the first, have well-developed postero-inferior processes. The first element has no distinct distal segment, but it is nevertheless possible that the bony loop which grows backwards from the hinder margin of the distal end of its proximal segment, and fuses with the contiguous extremity of the second proximal segment, may, as in the anterior dorsal fin, represent a fused distal segment. The first spine has a "chain-link" articulation with the proximal segment of the first radial element; the second a similar articulation with the bony loop between the proximal segments of the first and second elements; while the remaining soft rays clip the distal segments of their respective radial elements, the last two rays, however, being supported by the same distal segment.

Mesoprion gembra.

Dorsal fin.—Although a continuous structure, the dorsal fin consists of an anterior spinose portion and a posterior section composed of soft multiarticulate rays. The spinose portion consists of ten spines supported basally by a series of eight bisegmental (Pl. XXII. fig. 24, $r.e.^1$–$r.e.^1$) radial elements, all of which, including the first, have distinct hooked distal segments. Both in structure and in their articular relations to the spinose fin-rays, the radial elements are similar to the corresponding elements in *Perca*, except that neither the postero-superior processes of the proximal segments nor the distal segments develop lateral wing-like outgrowths, and hence there is no obvious bony groove for the deflected spines.

In addition to its normal spine, the third, the first radial element supports two additional spines, viz., the first and second, which are connected with the anterior portion of the distal end

of the proximal segment by "chain-link" articulations (*r.e.*[1], *p.s.*). Three vestigial proximal segments without fin-rays lie anterior to the first ray-bearing radial element.

In the soft posterior section of the fin there are fourteen radial elements, exclusive of a small vestigial proximal segment behind the last ray-bearing element. All are bisegmental (fig. 25) except the last four, which, curiously enough, possess a separable mesial segment, and are therefore trisegmental, and each supports a soft fin-ray. The connexion of the rays with the distal segment is by means of a "peg-and-socket" articulation in the case of the more anterior ones; posteriorly, however, the cleft rays merely embrace the distal segments.

Anal fin.—In this fin there are nine radial elements, of which the first to the sixth inclusive are bisegmental (Pl. XXII. fig. 26, *r.e.*[1]–*r.e.*[3]) and the last three trisegmental. The first supports three spines, two by means of "chain-link" articulations and the third by its hooked distal segment, precisely as in the first radial element of the dorsal fin. The remaining eight soft rays are also supported in much the same way as those of the hinder section of the dorsal fin.

There is a small vestigial proximal segment immediately behind the last ray-bearing element.

Sparidæ.

Pagellus centrodontus.

Dorsal fin.—In *Pagellus* the dorsal fin consists of twenty radial elements, of which the anterior ten support twelve spinose rays and the remainder a series of soft rays. Anterior to the first spine-bearing element three vestigial elements are represented by their massive T-shaped proximal segments without fin-rays. The spine-bearing elements are almost precisely similar to those of *Perca*. The postero-superior processes of the proximal segments and the distal segments possess unusually well-developed lateral wings, so that the groove for the deflected spines is exceptionally well marked.

In addition to its proper ray, the third, the first radial element supports two additional spines, of which the first has an incomplete "chain-link" articulation with the distal end of the proximal segment and the second a complete one.

The ten radial elements which support the soft rays are all bisegmental, resembling in this respect, as well as in the method by

which their rays are supported, the majority of the corresponding rays in *Perca*. The distal segment of the last radial element supports two rays, and in sutural connexion with the proximal segment of the same element there is a vestigial proximal segment which has no fin-ray.

All the distal segments in this portion of the fin appear to consist of two conjoined lateral halves separated by a distinct median longitudinal suture.

Anal fin.—There are ten bisegmental radial elements, and behind the last of the series a vestigial proximal segment similar to that in the dorsal fin. The first radial element supports three spines—two by "chain-link" articulations with the distal end of the proximal segment, and the third, the proper ray of this element, by the hooked distal segment. The remaining ten rays are soft and most of them have a "peg-and-socket" articulation with the distal segments of their respective radial elements. The distal segment of the last element, however, supports two rays.

Scombridæ.

Scomber scomber.

Although essentially similar in structure to those of the preceding Acanthopterygian Teleosts, there are nevertheless certain interesting variations in the structure of the dorsal and anal fins in this species. The dorsal fin consists of (*a*) an anterior spinose portion; (*b*) a median non-spinose section; and (*c*) a series of six detached finlets extending backwards to the root of the caudal fin. It is, however, worthy of note that so far as the supporting radial elements are concerned there is no interruption in the continuity of these externally distinct divisions of the fin. The anal fin also consists of an anterior section succeeded by six detached finlets.

Anterior Dorsal fin.—Fourteen radial elements are present, all of which are bisegmental. Each of the first nine consists of a proximal segment, with a postero-superior process, and a hooked distal segment. Both the postero-superior processes and the distal segment have well-developed lateral wings, and the mediodorsal bony groove of which they form the sections is, in consequence, unusually deep and broadly V-shaped. Towards the hinder end of the fin the proximal segments gradually diminish in size, and in the tenth radial element the distal segment loses its

hooked process. In the eleventh and succeeding elements the distal segments retain only a loose ligamentous connexion with the postero-superior processes of their proximal segments, and become entirely supported by the proximal segments of the next succeeding radial elements, instead of by two contiguous segments as is the case with the more anterior ones.

There are fourteen spinose fin-rays which gradually decrease in length from before backwards, the hinder ones being purely vestigial. The transversely elongated basal condyle of the first spine fits into a similarly disposed groove on the distal end of the proximal segment of the first radial element; the second spine has the usual "chain-link" articulation with the distal segment; and the remaining spines, as far as that normally belonging to the ninth element, have similar articulations. The succeeding spines have, however, simple cleft basal extremities, which clip the distal ends of the proximal radial segments immediately posterior to those to which they strictly belong. The last radial element has no proper spine, although it supports the spine belonging to the element immediately anterior.

Median Dorsal fin.—There are eleven radial elements, supporting a similar number of fin-rays, of which the first only is spinose. All the elements are bisegmental. The first has a hooked distal segment for articulation with the single spine; all the others have simple cubical distal segments, the more anterior of which have a "peg-and-socket" articulation with their fin-rays, the posterior being simply embraced by the cleft bases of the rays. Between the anterior and median divisions of the dorsal fin there is a continuous series of fifteen vestigial proximal segments in the form of slender splint-like ossicles, embedded in the median fibrous septum between the dorsal muscles, and indicating the primitive continuity of the two fins.

The Finlets.—Six radial elements support the six detached finlets, and form a continuous series with one another and with those of the median dorsal fin. Their adaptation for mutual support is brought about by the excessive elongation of their postero-superior processes, which enables each process slightly to overlap the base of the corresponding process of the next succeeding proximal segment. Each of the elements is bisegmental, and its distal segment is clipped in the usual fashion by the cleft base of the single multiarticulate and branched fin-ray of which each finlet is composed.

Anal fin.—The anterior division of the anal fin consists of twelve bisegmental radial elements, supporting thirteen fin-rays. The first element supports two spinose rays, the first by a "chain-link" articulation with the distal end of its proximal segment, and the second by an articulation with the hooked distal segment, in conjunction with a facet on the proximal segment of the second radial element. The remainder support soft rays in the ordinary way. The relations of the six radial elements supporting the six isolated finlets to one another and to those of the anterior part of the anal fin are precisely as in the dorsal fin.

Carangidæ.

Caranx georgianus.

Apart from variations in the number of radial elements and fin-rays and other minor differences, the dorsal and anal fins of *Caranx* are essentially similar to those of the more typical Acanthopterygii, such as *Perca* and *Pagellus*.

Sphyrænidæ.

Sphyræna Commersonii.

This Teleost is interesting as affording a transition from the more typical Acanthopterygii previously described to such families as the Cottidæ and Mugilidæ, in which more or fewer of the radial elements of the dorsal fin become unisegmental by the loss of their distal segments.

Anterior Dorsal fin.—The short anterior dorsal fin of this species consists of five radial elements (Pl. XXII. fig. 27) and an equal number of spinose rays. All the radial elements, except the last, are bisegmental, and the postero-superior processes of their proximal segments in conjunction with the distal segments form sections of a shallow medio-dorsal bony groove, as in many of the preceding types. None of the distal segments are hooked, and the method by which the fin-rays are supported is very unlike anything hitherto described. All the spines are furnished with imperforate bases terminating in a transversely elongated condyle. The first spine (*sp.r.*) articulates with a groove on the distal end of the proximal segment of the first radial element, but with all the remaining spines (figs. 27 and 28) the groove (*g*) for the reception of the condyle is formed by the distal

and proximal segments of two contiguous radial elements, the groove being bounded anteriorly by the posterior margin of a distal segment (*d.s.*), and behind and below by the anterior portion of the distal extremity of the next proximal segment (*p.s.*). As the second spine is the normal fin-ray of the first radial element, it is evident that the last element has no proper spine of its own, although it contributes to the formation of the groove for the fifth spine.

Three large T-shaped vestigial radial elements are situated immediately anterior to the first spine-bearing one.

Posterior Dorsal fin.—There are ten radial elements and eleven fin-rays. Of the radial elements the first five are bisegmental; the remainder, owing to the presence of mesial segments, are trisegmental. Behind the last there is a vestigial proximal segment partially fused with the corresponding segment of the antecedent radial element.

The first fin-ray is a spine, and its mode of articulation with the distal segment of the first radial element affords a further illustration of the method by which an ordinary cubical distal segment may become converted into a "hooked segment," with its characteristic articulation with the perforate base of a fin-ray. The distal segment in question is cubical anteriorly but behind contracts into a short, slightly curved hook-like process. The cleft base of the spine has two ingrowing processes, which, however, do not meet so as to bound a complete basal foramen; nevertheless, the hooked end of the distal segment fits into this incomplete foramen. The formation of the hook-like process seems, without doubt, to be due to the ingrowth of the two processes of the spine, and the consequent constriction of the posterior half of the segment to the condition of a relatively slender hook, which, however, still retains its normal position in the cleft of the spine. The distal segment of the second radial element is somewhat similar to that of the first, but more closely resembles the ordinary cubical distal segments of the rest of the fin, which are simply clipped by the cleft bases of the fin-rays. The last distal segment supports two feeble fin-rays.

Anal fin.—Nine radial elements and eleven fin-rays are present in this fin. The fin-supports are similar to those of the posterior dorsal fin, and, as in the latter, certain of them are trisegmental, viz. the sixth to the ninth inclusive, while the remainder are bisegmental. Behind the last of the series there is a vestigial

proximal segment suturally joined to the penultimate one. The first radial element supports two rays, and the last also two. The distal segments of the first two radial elements have incipient "chain-link" articulations with the second and third rays, as in the second dorsal fin.

Cottidæ.

Trigla gurnardus.

Dorsal fin.—This fin consists of a continuous series of twenty-nine radial elements supporting anteriorly eleven spinose rays and posteriorly nineteen soft, flexible, but unbranched rays. The first ten radial elements (Pl. XXIII. fig. 29) are unisegmental, consisting of proximal segments (*p.s.*) only. Each proximal segment is produced into a postero-superior process which is provided with well-developed lateral wings for the enclosure of a section of the medio-dorsal groove (fig. 29). The wings are somewhat contracted at their origin, but expand distally so as to overlap in an imbricated fashion the similar wings of contiguous segments, and, in consequence, the usual clefts between them for the transmission of the depressor and elevator muscles of the spines become converted into complete foramina (*f*). At the distal end of each proximal segment, near its anterior margin, there are two articular facets, one (*fc.*[1]) for articulation with the hinder margin of the postero-superior process of the proximal radial segment in front, and a second (*fc.*[2]), situated immediately in front of the first, for articulation with the condylar base of a spine.

The eleven spinose rays have imperforate bases terminating in a transversely elongated condyle, and in the absence of distal radial segments each spine is supported *solely* by the facet on the proximal segment immediately behind that to which it properly belongs. The second spine is that which strictly belongs to the first radial element, the first really belonging to an anterior suppressed element. The eleventh element supports the eleventh spine, in addition to the first of the series of flexible rays. The last three spines are more or less vestigial, and hence, externally, there is an apparent interruption in the continuity of the spinose and soft sections of the fin.

The remaining nineteen radial elements are precisely similar to those of the anterior portion of the fin except that they all possess nodular bony distal segments, which have the usual articulation with their own proximal segments and also with

those immediately posterior. The segments are clipped by the cleft bases of the soft rays.

Anal fin.—In this fin there are seventeen radial elements and nineteen fin-rays. The radial elements are all bisegmental and resemble those of the posterior section of the dorsal fin, except that the postero-inferior processes of the proximal segments have no lateral wing-like outgrowths. The fin-rays are also similar, but the first and last of the supporting radial elements carry each two rays.

Mugilidæ.

Mugil capito.

This species has an anterior and a posterior dorsal, and an anal fin.

Anterior Dorsal fin.—There are four radial elements (Pl. XXIII. fig. 30) consisting of proximal segments only, and a like number of spinose fin-rays. The distal end of each proximal radial segment forms a transversely elongated groove into which fits a similarly elongated condyle formed by the base of a spinose ray. The first three spines have perforated bases, the foramen being situated just above the basal condyle; the fourth, however, is imperforate. In addition to its basal support the first spine has a "chain-link" articulation with the first radial element; the second a "hook-link" articulation, the hook* being developed from the hinder margin of the distal end of the second radial element, and curving forwards so as to hook into the foramen in the base of its spine; the third, like the fourth, has a simple condylar articulation with its supporting radial element, although its base is perforate.

Posterior Dorsal fin.—In this fin there are nine radial elements and eight soft fin-rays. With the exception of the ninth, which has neither a distal segment nor a fin-ray, all the radial elements are bisegmental, and each supports a fin-ray. The fin-rays are cleft basally, and clip the distal segments of their respective radial elements.

Three vestigial unsegmented radial elements are present in the somewhat considerable interval which separates the two dorsal fins.

Anal fin.—There are ten bisegmental radial elements and thirteen fin-rays. The proximal segment of the first element

* Vide *Anarrhichas lupus*, p. 573.

has a "chain-link" articulation with the first ray, and, besides furnishing a hook-like process which curves backwards and hooks into the perforated base of the second ray, contributes by its distal segment to the support of its proper ray—the third. The remaining fin-rays clip their distal radial segments in the usual fashion, but the last two are both supported by the same distal segment, viz., that belonging to the last radial element.

Blenniidæ.

Anarrhichas lupus.

Dorsal fin.—In the long dorsal fin of this species there are seventy-five radial elements and seventy-six long flexible spinose fin-rays. All the radial elements are unisegmental (Pl. XXIII. fig. 31), consisting only of proximal segments (*p.s.*) without any trace of mesial or distal segments; and, with the exception of the last, all support in a precisely similar fashion their respective fin-rays. Near its distal extremity each proximal segment abruptly contracts into a nearly vertical postero-superior process, and from the anterior surface of this process a slightly curved bony hook extends forwards. The anterior extremity of the hook is connected by ligament with the distal end of the postero-superior process of the proximal segment immediately anterior, and I have no doubt that in this species, as with the second radial element of the anterior dorsal fin of *Mugil*, the hook owes its existence to the partial ossification of the ligament (interossicular ligament) which extends between the postero-superior processes of contiguous proximal segments. On the anterior side of the base of the postero-superior process there are two laterally situated facets (*fc.*) for the fin-ray.

Each fin-ray (*f.r.*) is cleft proximally into two basal arms, which converge somewhat without actually meeting, and finally terminate in two condylar extremities. Each ray is supported solely by a single radial element, partly by its two basal condyles which articulate with the two facets at the base of a postero-superior process, and partly by the extension of the hooked process of the latter through the nearly complete foramen enclosed by the cleft base of the ray. The rays are further retained in position by a stout longitudinally disposed ligament passing between their basal extremities, and also between the postero-superior processes of successive proximal segments. Of

the last two fin-rays, the first has the normal relations to the last radial element, but the second merely embraces the hinder margin of the postero-superior process.

It is worthy of note that, owing to the suppression of the distal segments of the various radial elements, each fin-ray is *solely* supported by its secondary connexion with the element immediately posterior to that to which it rightly belongs.

Anal fin.—The anal fin is altogether more normal in the structure and relations of its radial elements, of which there are forty-five, supporting an equal number of fin-rays. All the elements (Pl. XXIII. fig. 32, *r.e.*) have well-developed distal (*d.s.*) in addition to proximal (*p.s.*) segments, and the position and relations of the former are such that each is supported partly by the corresponding proximal segment, and partly also by that pertaining to the next succeeding element. The distal segments are apparently ossified from two lateral centres, and in the specimen examined, which was about two and a half feet in length, were still separated by an intervening tract of cartilage.

All the fin-rays are cleft proximally and embrace the distal segments of their supporting radial elements.

Labridæ.

Pseudoscarus superbus.

Dorsal fin.—There are eighteen radial elements and nineteen fin-rays. The first eight of the series of radial elements (Pl. XXIII. fig. 33, $r.e.^{6}$–$r.e.^{8}$) are all unisegmental, consisting only of proximal segments (*p.s.*). Each proximal segment is more or less dagger-shaped, with a short and nearly vertical postero-superior process, as in *Anarrhichas*. At its distal extremity a slender bar of bone passes from the base of the postero-superior process, and, curving downwards and forwards, fuses with the anterior margin of the segment in such a way as to form the outer half of a bony chain-link. The ninth proximal segment ($r.e.^{9}$, *p.s.*) differs from the preceding in the greater length and oblique backward prolongation of its postero-superior process, and also in the fact that it possesses an osseous distal segment (*d.s.*) for the support of the first soft ray in addition to the more anteriorly placed "chain-link" for the last of the spinose rays. The remaining elements are essentially similar to the ninth, although they have no "chain-link" and gradually decrease in size. Behind the

eighteenth, to the proximal segment of which it is suturally attached, there is a small osseous nodule which apparently represents an additional vestigial element.

The nine spinose rays have perforate bases for articulation by "chain-links" with the first nine of the series of radial elements. The ten soft rays, on the contrary, have the usual cleft bases for the reception of the distal segments of the radial elements from the ninth to the eighteenth, inclusive. Both the ninth and tenth soft rays, however, are supported by a single distal segment, viz., by that belonging to the last radial element.

The nature of the "chain-link" of the first nine radial elements appears somewhat puzzling. At first sight it seemed possible that it might owe its formation to the fusion of a hooked distal segment of one radial element with the anterior distal margin of the next succeeding proximal segment; but it is certain that no trace of any such fusion can be detected even if sections be taken through the possible line of junction and microscopically examined. On the other hand, it seems extremely probable that the chain-link results from a further extension of a modification already pointed out in the case of *Anarrhichas*, and also in the second radial element of the anterior dorsal fin of *Mugil*. If the hook-like process of a proximal segment in these Fishes were to curve forwards and downwards to a still greater extent, as the result of a further ossification of the interossicular ligament, and eventually fuse in front with the anterior margin of the segment, we should at once have a chain-link precisely similar to that of *Pseudoscarus*. This conclusion derives additional support from the essential similarity of the anterior radial elements of *Pseudoscarus* to those supporting the entire fin in *Anarrhichas*. In both genera the postero-superior processes are nearly vertical, and the fin-rays are supported solely by the radial elements immediately posterior to those to which they rightly belong.

Anal fin.—In the anal fin there are ten radial elements and twelve fin-rays. All the radial elements are bisegmental. Behind the last there is a vestigial proximal segment, without a fin-ray, as in the dorsal fin.

Of the three anterior spinose rays the first two articulate with the distal end of the proximal segment of the first radial element. The first spine is cleft proximally and simply clips the distal margin of the segment, while the second has a transversely

extended basal condyle fitting into a corresponding groove. The base of the third spine is perforated by a foramen, into which projects the contracted hinder end of the distal segment of the same element. The soft rays immediately behind the last spine have "peg-and-socket" articulations with the distal segments, but the more posterior rays simply embrace those segments in the usual manner. The distal segment of the last radial element supports the last two rays, the second of which probably belongs to the vestigial element.

Labrichthys tetrica.

This species very closely resembles the preceding in the character of its radial elements, and also in the mode of articulation of the fin-rays to their supporting elements. Anterior to the first of the ray-bearing series there is a vestigial element, in addition to one behind the last of the series.

FISTULARIIDÆ.

Aulostoma chinense.

Anterior Dorsal fin.—The continuous anterior spinose section of the dorsal fin of other Acanthopterygii is represented in *Aulostoma* by a series of eleven slender isolated spines, supported by a corresponding number of similarly isolated radial elements. Each radial element consists only of a proximal segment, which is transversely grooved at its distal end for articulation with a similarly modified condyle furnished by the uncleft base of a spinose ray. The various segments are almost horizontally disposed, the proximal extremity of each being directed forwards.

Posterior Dorsal fin.—In this there are twenty-five radial elements and twenty-seven soft fin-rays. All the radial elements, except the last two, are bisegmental, consisting of both proximal and distal segments, the former having well marked postero-superior processes, and both having the usual relations for mutual support. The last two of the series have a single large distal segment between them, and this supports four fin-rays. All the remainder support each a single fin-ray.

Anal fin.—This fin very closely resembles the posterior dorsal in all essential features.

Cyclopteridæ.

Cyclopterus lumpus.

Dorsal fin.—The hinder dorsal fin of this species, corresponding to the non-spinose portion of the dorsal fin of other Acanthopterygii, consists of ten soft rays, supported by an equal number of radial elements, all of which are bisegmental. The proximal segments of the radial elements are nearly straight, or at any rate are so slightly angulated at their distal extremities as to present only slight traces of postero-superior processes. The distal segments are small nodular ossicles. The connexion of the distal and proximal segments of the same radial element, and with those of contiguous elements, is loose and ligamentous, and there are no articular relations between the different elements for mutual support.

The basal ends of the cleft fin-rays are rugose and without basal articular surfaces: their cleft proximal extremities embrace the distal radial segments.

Anal fin.—This fin is precisely similar to the dorsal.

Trachypteridæ.

Regalecus argenteus.

From Parker's description and figures [1] of the dorsal fin of this species, it would seem that the supporting radial elements are bisegmental. Except for a short distance anteriorly each proximal radial segment is V-shaped, consisting of an anterior and a posterior arm, and a stem. The posterior arm is apparently the equivalent of the postero-superior process of other Teleosts, but the anterior arm is, so far as I am aware, peculiar. The segments are so arranged in longitudinal series that the distal extremity of the anterior arm of one abuts against the extremity of the posterior arm of the segment immediately anterior, while between the two, and supported to an equal extent by both, is the distal radial segment, clipped by the cleft base of its fin-ray. In the more anterior elements the two arms become merged in a single triangular plate. The first five proximal segments are partially fused and otherwise modified to support the fin-rays of the characteristic head-crest of this species.

There is no anal fin.

Lophobranchii.

Syngnathidæ.

Siphonostoma typhle.

Here is a well-developed dorsal fin and a small, almost vestigial anal fin.

Dorsal fin.—This fin consists of thirty-four bisegmental radial elements, supporting a like number of soft fin-rays. The proximal radial segments are very slender splint-like bones without any trace of lateral longitudinal ridges, and exhibiting a slight tendency to become arranged in groups of four each. In each group the segments converge slightly towards their proximal ends, where they are firmly attached to the summit of the neural arch of a subjacent vertebra. Distally, the segments diverge slightly and their dorsal extremities expanding somewhat come into apposition, and form with one another and with those of other groups a continuous peripheral margin. The distal segments consist of a series of rounded cartilaginous nodules connected with one another longitudinally by ligament, and but loosely connected by the same means with the distal extremities of the proximal segments.

The fin-rays are slightly bifurcate at their basal extremities and partially embrace the distal radial segments, to which they are intimately united by fibrous tissue.

Hippocampus guttulatus.

Except for reduction in number, the fin-rays and their radial elements in this species are essentially similar to those of the preceding.

Plectognathi.

Sclerodermi.

Balistes capriscus.

Anterior Dorsal fin.—The three spinose rays, with their osseous supports and muscles, in *Balistes vetula* have been described and figured by Sörensen [**10**]. The corresponding structures in *B. capriscus* are precisely similar, except for the diminutive size of the third spine. The radial elements supporting the

modified and highly specialized spines have apparently fused together to form a curious boat-like structure furnished with two large lateral foramina, through which are transmitted the depressor muscles of the first spine and the erectores of the second. Anteriorly this singular fin-support rests on the posterior face of the skull, and behind it is attached by ligament to the distal end of a fairly stout, shaft-like bone, the "tige apophysaire" of Holland *, the proximal extremity of which is in ligamentous connexion with the distal end of one of the anterior neural spines. The identification of the component elements of the fin-support is extremely difficult in adult specimens, and hence any comparison with the more normal elements of the posterior dorsal fin is likely to prove misleading. I am inclined to think that three radial elements enter into its formation, but to what extent the usual segments of these elements are represented I can offer no opinion.

Posterior Dorsal fin.—In this fin there are twenty-seven radial elements, supporting a corresponding number of soft, branched and multiarticulate fin-rays. All the radial elements (Pl. XXIII. fig. 34, *r.e.*) are bisegmental, each consisting of a proximal (*p.s.*) and a distal (*d.s.*) segment. The proximal segments exhibit a general resemblance to the ordinary dagger-shaped bones of other Teleosts, and for the greater part of the length of their parallel and serrated anterior and posterior margins are in close sutural connexion with one another, the union in those more posterior extending even to partial anchylosis; they also interdigitate with the subjacent neural spines, to which they are firmly and rigidly attached. Superiorly, the proximal segments terminate in cartilaginous extremities, which are in close apposition and form an even dorsal margin traversed by a slight longitudinal groove for articulation with the series of distal segments. On the outer surface of each proximal segment there is a prominent longitudinal bony ridge, which, however, ceases a little short of the extreme distal end of the segment.

The distal segments, on the contrary, are small, somewhat cubical, cartilaginous nodules with flat distal and convex proximal surfaces, and so arranged that while in close ligamentous connexion with one another in a longitudinal series they tend to alternate with the proximal segments. The connexion

* Quoted by Sörensen, *l. c.*

between the distal and proximal segments is less intimate than in most other Teleosts. To some extent the series of distal segments articulate with the longitudinal groove on the distal margin of the series of proximal segments, and a short, relatively stout ligament passes from each distal segment to the subjacent proximal segments; but the articulation between the two series of segments is, nevertheless, unusually mobile—in fact, the connexion of the distal segments with one another is much more intimate than is their relation to the series of rigidly interconnected proximal segments.

Each fin-ray (*f.r.*) is cleft basally and the two arms, which terminate inferiorly in thin, plate-like expansions, and not in articular surfaces, closely and firmly clip a distal radial segment.

Anal fin.—In the anal fin there are twenty-four radial elements and a corresponding number of soft fin-rays, both of which in structure and in mutual relations precisely resemble those of the posterior dorsal fin.

Monacanthus granulosus.

As in *Balistes*, this species is provided with a short spinose anterior dorsal fin and a soft posterior one, in addition to an anal fin.

Anterior Dorsal fin.—Sörensen [**10**] has also figured and described the two spines with their supports and muscles in *M. pardalis*, to which species *M. granulosus* exhibits a fairly close resemblance in so far as the structures in question are concerned. The bony support for the spines is somewhat similar to that of *Balistes capriscus*, but is shallower, with the two lateral foramina replaced by notches, and, as it is wholly supported by the hinder part of the cranial roof, the "tige apophysaire" is wanting. As in *Balistes*, the fin-support bears no resemblance to the ordinary radial elements of the posterior dorsal fin, and no suggestion can therefore be offered as to the number or nature of such elements, or their segments, which enter into its formation.

Posterior Dorsal fin.—This fin is very similar to the corresponding fin in *Balistes*, and consists of twenty-eight or twenty-nine radial elements and a corresponding number of soft rays. The proximal radial segments are firmly connected with one another by squamous sutures, and also with the subjacent neural

spines between which they are interposed. In addition to the lateral longitudinal bony ridge, each segment is furnished with two lateral bony processes projecting outwards at right angles to its long axis from a point a little below its distal end. The distal segments are also similar to those of *Balistes* in their relations and connexions *inter se*, the mobility of their articulation with the proximal segments, and in their mode of insertion into the cleft bases of their fin-rays.

Anal fin.—In almost every respect the anal fin is similar to the posterior dorsal fin.

Gymnodontes.

Tetrodon immaculatus.

Dorsal fin.—In this species the single short dorsal fin, which is apparently the equivalent of the posterior dorsal fin of the preceding species, consists of ten soft rays supported by a series of seven radial elements (Pl. XXIII. fig. 35, *r.e.*^{1}–*r.e.*^{7}). All the elements are bisegmental. Their proximal segments (*p.s.*) are elongated and somewhat irregular in shape, without any trace of the usual lateral longitudinal ridges, and all are more or less firmly connected together for a portion of their length by squamous sutures. The cartilaginous distal extremities of the segments fuse together into a continuous peripheral margin (*c.m.*), which is separated from, but at the same time loosely connected with, the distal segments by an intervening tract of fibrous tissue (*l.g.*).

The distal segments are represented by a series of simple, cubical, cartilaginous nodules (*d.s.*), widely separated from the proximal segments, although corresponding with them in number. As in the two preceding species, the distal segments are intimately connected together in a longitudinal series by fibrous tissue.

The ten fin-rays have cleft bases, into which are inserted the supporting distal radial segments. Towards the hinder part of the fin more than one ray may be wholly or in part supported by the same distal segment.

Anal fin.—In this fin there are only four radial elements (fig. 36, *r.e.*^{1}–*r.e.*^{4}), but at least ten soft fin-rays. The proximal radial segments (*p.s.*) are firmly connected together although, perhaps, less intimately than in the dorsal fin, and the first of

the series is exceptionally long and stout. The four cartilaginous nodules representing the distal segments (*d.s.*) do not correspond in position with the dorsal extremities of their proximal segments, but are concentrated towards the anterior border of the fin, and support in the usual manner the first four fin-rays. The remaining rays have their bases imbedded in a posterior extension of the fibrous tissue (*l.g.*), which in the anterior part of the fin connects the fused cartilaginous extremities of the proximal segments with the distal segments. In all other respects the anal fin closely resembles the dorsal.

Diodon hystrix.

Dorsal fin.—There are eleven proximal radial segments (Pl. XXIII. fig. 37, *p.s.*), all of which, except the first and last, are cylindrical for the middle portion of their length, but fused distally into a continuous, dorsally grooved, cartilaginous margin (*c.m.*), while their expanded and cartilage-tipped proximal extremities are suturally united and at the same time firmly wedged in between the neural spines of the subjacent vertebræ. The first and last of the series are much more massive and differ somewhat in shape from the others. The distal segments (*d.s.*) are more numerous than the proximal, being sixteen in number. The first is thick and cubical in shape; the remainder are more or less elongated cartilaginous rods, except the last two or three, which are much shorter and approximate to the condition of simple nodules. The fin-rays are also sixteen in number, and their bifid basal ends (fig. 38, *f.r.*) ensheath the distal radial segments (*d.s.*).

Anal fin.—This fin consists of nine proximal radial segments, fifteen distal segments, and fifteen soft fin-rays, but in all other respects it is almost precisely similar to the dorsal fin.

Orthagoriscus mola.

The fins and fin-supports of this species, with the remaining portions of the skeleton, have been described and figured by Wellenbergh [13] and Cleland [14]. As far as the fins are concerned, Cleland's account and figures are on the whole the more detailed and accurate, but in some respects his description is either incomplete or not sufficiently clear to admit of the comparison of these structures with those of other Teleosts. For this reason I have thought it desirable to revise Cleland's

account in the light of an examination of a specimen of the same species which I have recently had the opportunity of dissecting.

Dorsal fin.—In all essential features this fin closely resembles that of *Diodon hystrix*. In the series of radial elements there are fifteen proximal segments and seventeen distal. Of the proximal segments, the first differs in shape from the others, and, as it takes no share in the support of the fin-rays, simply acts as a buttress to the second, to the anterior margin of which it is closely applied. The remaining proximal segments are expanded and flattened out at their proximal extremities, where they are in close contact with one another and, at the same time, wedged in between the vertebral neural spines. Towards their distal ends the segments contract and become nearly cylindrical, and, finally, their cartilaginous distal extremities fuse indistinguishably into an exceptionally thick, longitudinally disposed mass of cartilage, which is marked by a longitudinal groove along its dorsal border and traversed by a succession of deep vertical grooves on each of its lateral surfaces for the passage of the tendons of the fin-muscles.

The distal segments vary considerably in size and shape. The first is short, thick, and somewhat flattened laterally; the succeeding four or five rapidly elongate and become thick, four-sided, tapering cartilaginous rods; those following, while retaining much the same shape, gradually diminish in length and become more slender; while the last two or three of the series are irregularly shaped cartilaginous masses. All the distal segments are firmly connected with one another by ligament, and their rounded proximal ends fit into the longitudinal groove on the dorsal margin of the proximal segments; they are also in ligamentous connexion with the proximal segments, but the union is, nevertheless, of such a character that the distal segments and their fin-rays are capable of a considerable range of ateral movement on their basal supports.

The fin-rays agree in number with the distal radial segments. Of the anterior six the first is short, but the others, rapidly increasing in length, remain undivided and support the relatively unyielding anterior margin of the fin. The remaining eleven rays fray out, as it were, at the distal ends and, gradually diminishing in length, support the flexible cutaneous fold which fringes the posterior margin of the fin from its apex downwards.

Each fin-ray is cleft longitudinally for the proximal three-fourths of its length, and its lateral halves expand towards the base of the ray into thin splint-like plates, and firmly embrace between them for nearly its whole length one of the distal radial segments. In striking contrast to their massive supporting cartilages, the posterior two or three rays are very feebly developed.

Anal fin.—In the anal fin there are eleven proximal radial segments, and fifteen distal segments supporting a like number of fin-rays. Except for the partial fusion of the first two proximal radial segments, the fin and its fin-supports differ but little from the description of the dorsal fin given above.

III. SUMMARY.

In this section it is proposed to institute a comparison of the principal modifications of the radial elements of the mesial fins with regard to their degree of segmentation, the extent to which they are affected by degeneration and concrescence, and the variable modes of support they offer to the fin-rays, in different groups of Fishes.

The most primitive type of radial element is to be found in the Marsipobranchs, where they exist in the form of unsegmented cartilaginous rods, either simple or dichotomously branched towards their distal ends, and, in the absence of horny fibres or fin-rays, they extend to the peripheral margins of the fins and constitute their sole skeletal support.

In retaining the condition of simple unsegmented cartilaginous rods, the radial elements of the Holocephala resemble those of the Marsipobranchs; but how far the simplicity of these structures is primitive, or has been acquired by the suppression of segments, cannot at present be determined. Actinotrichia in the form of horny fibres support the periphery of the fins.

In the most primitive of extinct Elasmobranchs (e. g. *Cladoselache, Pleuracanthus*) the radial elements of the dorsal fins become complicated by segmentation, each being divided into a basal and a distal segment, of which the distal is the longer. As pointed out by Dean [11], the various elements extend to the periphery of the fin and in conjunction with horny fibres, which in *Cladoselache* are of secondary importance and lie between the former, contribute to the support of the fin.

In the Arthrodira (e. g. *Coccosteus*) [Smith Woodward, 12] the radial elements are very similar bisegmental structures.

In existing Elasmobranchs the typically rod-like cartilaginous radial elements are generally trisegmental, exhibiting a division into proximal, mesial, and distal segments, flexibly connected with one another by ligament, and in fairly close apposition throughout their length for mutual support. The central or approximately central elements are usually the longest, and almost invariably the most anterior and posterior undergo reduction in length and lose one or more of their constituent segments—facts which find their legitimate explanation in the partial atrophy of an originally more extensive fin and the concentration of the persistent residue of the fin-supports. The horny fibres, as was probably also the case in the fossil Elasmobranchs above-mentioned, are much more numerous than the supporting cartilages, and to a greater extent than in extinct types they supplant the latter in supporting the flexible peripheral margins of the fins. As has already been pointed out, the radial elements are liable to considerable modifications in different genera through (*a*) the longitudinal concrescence of the proximal segments, or of both proximal and mesial; (*b*) the suppression of particular segments in certain of the elements; and (*c*) the apparently secondary subdivision of the distal segments.

The polymorphic character of existing Ganoids is well illustrated by the existence of striking variations in the structure of the radial elements, of which three well-marked types are represented within the limits of the group.

(1) In *Acipenser* and *Polyodon* the trisegmental radial elements are essentially similar to those of Elasmobranchs in shape and mutual relations, in the large relative size of the mesial segments, the tendency to occasional concrescence on the part of the proximal segments, the excess in the number of dermal fin-rays which they support, and also in the fact that the cleft bases of the fin-rays embrace between them not only the distal but to some extent the mesial segments also. On the other hand, there are not wanting indications of increasing specialization in the partial ossification of the proximal and mesial segments, and the reduction of the distal segments to the condition of simple cartilaginous nodules. The fin-rays also exhibit modifications in the same direction. Not only are they partially ossified, but, although more numerous than the supporting radial elements,

there is not that marked disparity which is so characteristic of Elasmobranchs. Their reduction in number, as well as their increase in size, is presumably due to the fusion of primitive "actinotrichia;" and, in consequence of the more deeply seated position of the radial elements, they now become the chief support of the external portions of the fins.

(2) In *Amia* and *Lepidosteus* the radial elements exhibit a decided approximation to the condition of these structures in the more generalized Teleosts. They are trisegmental, each element consisting of an ossified dagger-shaped proximal segment, an hour-glass-shaped mesial segment also ossified, and a nodular cartilaginous distal segment. The various segments afford mutual support to one another, not by their parallelism and apposition, but by the articulation of the mesial and distal segments of one element with the proximal and mesial segments of that next succeeding. A marked reduction in the number of fin-rays has taken place, and each radial element has now but a single ray, which is cleft basally and clips the distal segment of its proper radial element; but from what has been said as to the articular relations of the segments of contiguous elements, it is obvious that two elements contribute directly or indirectly to the support of each ray. The dermal fin-rays are now the exclusive support of the externally visible portions of the fins, the radial elements having become deeply seated between the dorso-lateral muscles of opposite sides of the body—a position which they retain in the remaining Ganoids and in all Teleosts. Indications of suppression of segments of particular elements are not wanting, and, as in Elasmobranchs, they are characteristic of the more anterior or posterior of the supporting elements of the fins, which, in consequence, may become bisegmental or even unisegmental. The fact that in *Lepidosteus* the first and last of the radial elements of both the dorsal and anal fins support one or two rays, in addition to the single ray which normally belongs to each, is probably due to the concentration of certain rays which have lost their radial elements during the atrophy of a primitively more extensive fin, on the first and last of the persistent residue of the fin-supports. The presence of vestigial radial elements (*Amia*) between the dorsal and anal fins indicates the primitive continuity of these structures.

(3) The third type, represented by *Polypterus*, is of a singularly aberrant character. The simple bisegmental elements of the

more primitive anal fin cannot readily be compared with those of other Ganoids. The dorsal and ventral segments of each element may correspond to the proximal and mesial segments of other Ganoids, the distal segment having been suppressed, but it is by no means clear that this is the correct interpretation. I am inclined to think that the counterpart of this type of fin-support must be looked for in older and more primitive forms. Comparison with the simple bisegmental radial elements of the dorsal fins of such ancient Elasmobranchs as *Cladoselache* and *Pleuracanthus*, or of such Arthrodira as *Coccosteus*, reveals a very close agreement with *Polypterus*, and suggests that the latter has retained in its anal fin a more primitive type of fin-support than any living fish except, perhaps, the Marsipobranchs. Further indications of the primitive character of the anal fin of *Polypterus* are to be found in the absence of the characteristic articulation between contiguous radial elements which is so marked a feature in *Amia* and *Lepidosteus*, and in the fact that the dermal fin-rays are twice as numerous as their supporting elements.

The radial elements of the dorsal fin present a striking contrast to those of the anal fin. That their simple unsegmented condition is not due to the retention of a primitive character, but, on the contrary, is the result of specialization, is suggested by the size of the structures they support. The spines of the anterior part of the fin, and even the multiarticulate branched rays of the hinder part, are exceptionally massive, and the segmentation of the supporting elements would obviously detract somewhat from their value as skeletal supports for the former. Hence, whatever may have been the primitive condition of the fin-supports, and the probability is that they resembled those of the anal fin, it seems legitimate to infer that the reduction of each element to a single segment is correlated with their function as supports for exceptionally large dermal fin-rays. A precisely similar modification and reduction is frequently associated with the development of unusually large spines in many Teleosts *. But if this explanation be correct, it might reasonably be anticipated that fossil Crossopterygidæ with soft fin-rays would throw some light on the primitive character of the fin-supports in this group; but unfortunately the evidence available from this source, although not opposed to the suggestion, is by no means conclusive. In

* See also *Aulostoma chinense*, where a modification very similar to that referred to in *Polypterus* has taken place in the anterior dorsal fin.

Eusthenopteron Foordi, Whiteaves, the radial elements in both the dorsal and anal fins are apparently bisegmental, but the basal segments in each fin are confluent, although three distal segments are distinct and support the numerous fin-rays. In *Undina gulo*, Egerton, two radial elements are present in each fin, which are fused distally but distinct and divergent proximally; and in *Diplurus longicaudatus*, Newberry, the fin-supports of the two dorsal fins have fused into a single piece in each case, which dorsally supports the dermal fin-rays. The fin-supports of *Eusthenopteron Foordi* are obviously derived from a primitive bisegmental type; but it is equally clear in this species, as well as in *Diplurus* and *Undina*, that the structures in question have undergone considerable specialization in which concrescence has played an important part.

In several families of Physostomous Teleosts, viz., the Osteoglossidæ, Murænidæ, Esocidæ, Cyprinidæ, Salmonidæ, and possibly in others, more or fewer of the radial elements of both the dorsal and anal fins are trisegmental; and in this respect, as well as in the relations of the segments of contiguous elements for mutual support, these families more or less closely resemble the Ganoid genera *Amia* and *Lepidosteus*. Of the five families, the Osteoglossidæ and the Murænidæ are undoubtedly the most primitive in so far as the character of the fin-supports is concerned, and approach most closely to the two Ganoid genera. In the Murænidæ (*Conger* and *Anguilla*) all the radial elements are trisegmental; and there is no concentration of fin-rays on the first or last of the series, each element possessing only a single ray. In the Osteoglossidæ suppression has slightly modified certain elements to the extent that the last two in the dorsal and anal fins have lost their distal segments.

In the three remaining families there is a tendency to a variable reduction in the number of radial elements which retain the primitive trisegmental character, the reduction affecting the more anterior and posterior of the series, which in consequence become bisegmental or even unisegmental. The reduction in the case of the anterior elements is undoubtedly associated with the requirements of a firm support for the large and often spinose anterior dermal fin-rays; in the case of the posterior elements the reduction is clearly due to degeneration, and is invariably associated with the presence of feebly developed rays or their absence (e. g. *Barbus*). The extent to which reduction modifies

the character of the radial elements of different portions of the dorsal fin in these families may be represented in the following Table.

Name of Species.	Number of radial elements.	Trisegmental.	Bisegmental.	Unisegmental.
Esocidæ.				
Esox lucius	20	6–15	2–5, 16–20	1
Cyprinidæ.				
Barbus vulgaris ...	10	5–9	1–4	10
Cyprinus carpio ...	22	3–21	1–2	22
Salmonidæ.				
Coregonus pollan...	12	6–11	3–5	1–2, 12

The existence of trisegmental radial elements in Teleosts has not previously been recorded, at all events so far as I have been able to discover. The development of the radial elements has been studied by Harrison [3]; and from the results of his investigations in *Salmo salar* and *Carassius auratus* it would appear that each element first makes its appearance in the form of a somewhat curved cartilaginous rod or "Flossenstrahlträger," the convexity of which is directed forwards. "Schliesslich bildet sich aus dem undifferenzirten Gewebe am Ende jedes Flossenstrahlträgers ein kleiner kugelförmiger Knorpel, mit dem sich der Flossenstrahl eng verbindet. Jedes Flossenstrahlpaar umgreift die knorpelige Kugel mit ihrem centrale Ende, welches zu einem kurzen und beinahe horizontalen Fortsatz umgebogen ist, und zwei Gebilde vereinigen sich vollständig vermittelst eines starken Bindegewebes" (*l. c.* p. 521). No mention is made of mesial segments, although such segments are undoubtedly present in both the Salmonidæ and Cyprinidæ in the adult state, but it is probable that the omission is due to the fact that Harrison's investigations were principally directed to the origin and metameric relations of the fin-muscles, and ceased at a much earlier stage than that at which the radial elements attain their adult characters. As regards the origin of the mesial segments, two alternative methods may be suggested. It is of course possible that, like the distal segments, they owe their formation to the chondrification of indifferent connective tissue between the "Flossenstrahlträger" and the cartilaginous nodule representing the distal segment at a later stage; or it may be

that they result from secondary segmentation of the distal part of the "Flossenstrahlträger." The latter of the two suggestions seems the more reasonable; for the curvature of the "Flossenstrahlträger" is strongly suggestive of the similarly bent shape of an ordinary proximal and mesial segment taken together. It is nevertheless probable that the cutting-off of the mesial segment may in some cases precede ossification, while in others it may be the result of the appearance of a separate centre of ossification at the distal end of the "Flossenstrahlträger." *Lepidosteus* and *Amia* are, perhaps, examples of the former method, inasmuch as in these genera the cartilage-tipped mesial segments are separated by a very evident suture from the similarly tipped distal extremities of the proximal segments. On the other hand, in *Esox* (Pl. XXI. fig. 11), and possibly in other Teleosts with trisegmental elements, the second method has been the one adopted, the mesial segments in the more anterior radial elements of the dorsal fin being represented by small ossific centres in the unsegmented cartilaginous extremity of a backwardly curved "Flossenstrahlträger."

The existence of separable mesial segments in Teleosts, not only in the families above mentioned but also in certain Acanthopterygii, renders it possible to regard the radial elements of Teleosts as typically trisegmental, and therefore directly comparable with the corresponding structures in Ganoids (excluding *Polypterus*) and existing Elasmobranchs.

As regards the relative constancy of the three typical segments of a radial element, it seems reasonable to infer, from the order of their suppression, that not only in the families above mentioned, but in Teleosts generally, the proximal segment is the most constant, that the distal segment is next constant, while the mesial is apparently the least constant and that most likely to disappear first.

In the Physostome families the Siluridæ, Characinidæ, and the Clupeidæ the radial elements are either bisegmental or unisegmental, never, owing to the absence of a distinct mesial segment, trisegmental: very rarely is it the case, as in some Siluridæ (e. g. *Cnidoglanis*), that a functional dorsal fin has no radial elements but is supported solely by its fin-rays. In the Characinidæ (*Citharinus*) and the Clupeidæ (*Clupea*) all the radial elements in both fins are bisegmental, consisting of proximal and distal segments. In the Siluridæ (*Platystoma*, *Amiurus*), while the great majority of

the elements remain bisegmental, more or fewer of the anterior ones become specialized for the support of powerful defensive spines, and in consequence lose their distal segments and become unisegmental, as, for example, the first two elements of the dorsal fin. On the other hand, in the Gymnotidæ the distal segments are either entirely wanting or are represented by simple fibrous pads interposed between the fin-rays and the distal extremities of the proximal segments.

It is nevertheless interesting to note that in the Clupeidæ and Siluridæ, as in so many other Teleosts, the distal extremities of the proximal radial segments of the dorsal fin, with the occasional exception of the more anterior of the series, are produced obliquely upwards and backwards into well-marked postero-superior processes, which in their relations to the distal segments, as well as in their articulation with the proximal segments of the next succeeding elements, exhibit a striking resemblance to the mesial segments of *Amia* and *Lepidosteus* and of those Physostomi with trisegmental elements. There is, however, no evidence that these processes are mesial segments which have fused with the proximal segments, or that they can be looked upon in any other light than as modifications of the distal extremities of ordinary proximal segments that have taken the place of the missing mesial segments; and this conclusion is supported by the fact that in some Teleosts (e. g. *Regalecus*) similar processes, but antero-superior in position, may be developed from the distal ends of the proximal segments and exist in conjunction with ordinary postero-superior processes *. In the Characinidæ (*Citharinus*) these processes are entirely wanting, and the proximal segments derive mutual support from the simple apposition of their distal extremities. In the Gymnotidæ (*Gymnotus*) not only are postero-superior processes undeveloped, but the proximal segments have no articular relations, and except for their ligamentous connexion are quite distinct from one another †.

As regards the ossification of the radial elements, the proximal, and the mesial segments when present are invariably ossified:

* It is not altogether improbable, however, that a proximal segment and its postero-superior process may correspond to Harrison's "Flossenstrahlträger," and therefore represent an undivided proximo-mesial segment ossified continuously from a single centre.

† The proximal radial segments of the anal fin very generally possess oblique postero-inferior processes which are similar in their mutual relations to the postero-superior processes of the dorsal fin.

the distal segments are variable in this respect, and may either be simple cartilaginous nodules (*Esox*), or become ossified (*Cyprinus*, *Barbus*, *Osteoglossum*, *Citharinus*), in some (e. g. *Cyprinus*) from two lateral centres.

Lateral longitudinal ridges on the outer surfaces of the proximal radial segments are now generally present, as in most other Teleosts, and serve to increase the surface available for the origin of the erector and depressor muscles of the fin-rays.

In the Anacanthini, represented by the Gadidæ (*Gadus*, *Merluccius*) and the Pleuronectidæ (*Pleuronectes*), the radial elements, with the occasional exception of the last of the series, are bisegmental, mesial segments being invariably wanting. The persistence of simple nodular distal segments, usually cartilaginous, throughout the series, even in the anterior elements, is evidently associated with the absence of spinose fin-rays. In the Gadidæ the proximal segments possess well-developed postero-superior processes in the dorsal and postero-inferior processes in the anal fin, with the usual articular relations with the distal segments and with contiguous proximal segments. In the Pleuronectidæ these processes are wanting, the proximal segments being in simple parallel apposition.

In the Acanthopterygian Teleosts, as might be expected, there is a wide range of variation in the condition of the radial elements. The only families in which the trisegmental type occurs are the Berycidæ (*Holocentrum*), Percidæ (*Mesoprion*), and the Sphyrænidæ (*Sphyræna*). In *Holocentrum*, *all* the ray-bearing elements of the posterior non-spinose section of the dorsal fin, and, with the exception of the first three, all those of the anal fin are trisegmental. In *Sphyræna* only the last five of the soft portion of the dorsal fin and the last four of the anal fin are trisegmental; and in *Mesoprion* the last four of the posterior dorsal fin and the last three of the anal fin. The remaining elements of the posterior dorsal and the anal fins of the last two genera and the first three of the anal fin in *Holocentrum* are bisegmental, as also are those which support the anterior spinose section of the dorsal fin in all three genera *. In the remaining Acanthopterygii,

* It may be remarked that *Holocentrum* is a modern representative of one of the oldest families of existing Teleosts; and from this point of view the fact that the radial elements of the hinder section of the dorsal fin and the anal fin retain their primitive trisegmental character to a greater extent than in any other living Acanthopterygii is of considerable interest.

excluding the Blenniidæ, the supporting elements of the hinder soft-rayed portion of the dorsal fin and also those of the anal fin (if present) are bisegmental; and the same may be said of the fin-supports of the spinose portion of the dorsal fin in the Percidæ, Sparidæ, Scombridæ, and Carangidæ, and of the whole dorsal fin of the Trachypteridæ. On the other hand, in the Cottidæ, Mugilidæ, Labridæ, and Fistulariidæ the anterior spinose dorsal fin is supported by radial elements which consist only of proximal segments, and are therefore unisegmental. In the Blenniidæ the whole of the extensive dorsal fin is supported by unisegmental elements. As a rule, the posterior soft-rayed part of the dorsal fin and the anal fin more or less closely agree in the character of their radial elements; the Blenniidæ, in which the elements of the dorsal fin are unisegmental while those of the anal are bisegmental, being the only family in which there is any marked difference between the two series.

Indications of the suppression of segments are not wanting in fins in which the majority of the radial elements are either trisegmental or bisegmental: this is apparent, for example, in *Perca*, where the last three elements of the spinose part of the dorsal fin have lost their distal segments, and in *Aulostoma*, where the last two of the posterior dorsal fin are similarly modified.

In nearly all the Acanthopterygii the proximal radial segments of the dorsal and anal fins are furnished with postero-superior or postero-inferior processes with the usual articular relations: they are, however, usually wanting in the more anterior elements of each fin.

In the more typical Acanthopterygii, such as the Berycidæ, Percidæ (excluding *Mesoprion*), Sparidæ, and the Scombridæ, the postero-superior processes in the spinose part of the dorsal fin, and the distal radial segments which articulate with them, are laterally expanded and bent upwards so as to form sections of a continuous, medio-dorsal, bony groove for the reception of the spines when deflected. In the Cottidæ, where distal segments are wanting, the postero-superior processes are alone concerned in the formation of the groove. In others, as in the Blenniidæ, the groove is absent. Occasionally, through their considerable increase in length, the postero-superior and postero-inferior processes serve to connect together the otherwise widely separated radial elements which support externally distinct fins or finlets,

as is the case with the isolated dorsal and ventral finlets of *Scomber*. In the Trachypteridæ (*Regalecus*) only are the proximal radial segments provided with antero-superior processes either singly or in conjunction with postero-superior ones.

In the Lophobranchii, as represented by the Syngnathidæ (*Siphonostoma*), the radial elements of the dorsal fin are all bisegmental, consisting of proximal and distal segments only. The proximal segments are simple elongated ossicles, without lateral longitudinal ridges or postero-superior processes, and are in simple apposition by their cartilage-tipped distal extremities. The distal segments agree in number with the proximal, and are simple cartilaginous nodules connected with one another by ligament in a longitudinal series.

In the Plectognathi the radial elements are essentially similar in the single dorsal and the anal fin of the Gymnodontes (*Diodon*, *Tetrodon*, and *Orthagoriscus*), and in the posterior dorsal and anal fins of the Sclerodermi (*Balistes*, *Monacanthus*), but are modified by fusion, and in other respects, in the anterior dorsal fin of the two latter genera. In the Sclerodermi the cartilaginous distal extremities of the proximal radial segments, although in close apposition so as to form an even dorsal margin for articulation with the distal segments, are nevertheless distinct; in the Gymnodontes, on the contrary, the extremities fuse into a continuous margin of cartilage traversed by a longitudinal groove for articulation with the series of distal segments. In the Sclerodermi, and in *Tetrodon* among the Gymnodontes, the distal segments agree in number with the proximal; but in *Diodon* and *Orthagoriscus* the former are the more numerous, and agree numerically with the fin-rays they support. In the two last-mentioned genera the distal segments, instead of being small in size and cubical in shape, assume the form of elongated cartilaginous rods, a condition which exists in no other Teleosts. The Gymnodontes are also peculiar among Teleosts in that the vertebral extremities of the proximal radial segments are provided with cartilaginous epiphyses.

Vestigial radial elements in the form of slender rod-like ossicles, or flattened lamellar bony plates, are of frequent occurrence in Teleosts, and apparently represent persistent proximal segments which have lost their dermal fin-rays. Very often there is a single vestigial element immediately posterior to the last ray-bearing element of the dorsal fin (e. g. *Holocentrum*, *Mesoprion*, *Sphyræna*), and not infrequently a more or less extensive series

is to be found in front of the first. Thus in the latter position there may be only one vestigial element (e. g. *Perca*), or three (*Mesoprion*, *Pagellus*, *Caranx*), or seven (*Citharinus*) or eight (*Abramis*); and in a few instances the number may be so considerable as to extend the series to the posterior face of the skull, as, for example, where the numbers are seventeen (*Coregonus*), or eighteen (*Clupea*). In some instances such vestigial elements are interposed between the ray-bearing elements of fins which externally are discontinuous: thus, between the mesial and posterior dorsal fins of *Gadus æglefinus* there are three vestigial elements; between the anterior and posterior dorsal fins of *Scomber scomber* fifteen; and in a similar position in *Mugil capito* three. The presence of these ossicles must be regarded as indicating the existence of a primitively more extensive dorsal fin; and in the case of *Scomber*, *Gadus*, and *Mugil* proves also the original continuity of fins which in the adult are distinct. No vestigial elements are ever present anterior to the first ray-bearing element of the anal fin, although somewhat rarely there may be one behind the last.

Radial elements are in ligamentous connexion with one another; and in the absence of definite articulations, *inter se*, this may be the only bond of union between them (e. g. *Cyclopterus*). Where the elements are trisegmental, a ligament (interossicular ligament) extends backwards from each distal segment to the mesial and distal segments of the next succeeding element. In the absence of a mesial segment, the postero-superior or postero-inferior process takes its place as a point of attachment for the ligament; and when both mesial and distal segments are wanting, the ligament extends between the distal extremities of successive proximal segments. In some genera the ossification of the ligaments, or of portions of them, may give rise to bony hook-like processes for articulation with the dermal fin-rays (*Holocentrum*, *Mugil*, *Anarrhichas*).

Relations of the various Segments of the Radial Elements to the Dermal Fin-rays in different Teleosts.

As in *Lepidosteus* and *Amia*, so in the majority of Teleosts, each element normally possesses only a single fin-ray; but owing to the fact that the distal segments which directly support the fin-rays articulate not only with the mesial or, in their absence, the proximal segment of the same radial element, but also with the proximal segment of the next succeeding element, it is very

generally the case that two elements contribute directly or indirectly to the support of each ray. In certain families, however, as the result of the suppression of both mesial and distal segments, either in the entire dorsal fin or in the anterior section of it, the fin-rays become disassociated from their own proper elements, and are supported solely by the proximal radial segments immediately posterior to those to which they really belong (*e. g.* Blenniidæ, Labridæ). In only one or two families (*e. g.* Cyclopteridæ), and probably as the result of degeneration, are the fin-rays exclusively supported by their own proper radial elements. Evidence of the concentration of fin-rays is apparent in the dorsal and anal fins of most Teleostean Fishes. Thus, the first radial element of the dorsal fin in *Esox* and *Coregonus* supports two rays, of which the second is, without doubt, its proper ray; in *Barbus* and *Cyprinus* it supports three rays in addition to the fourth—the proper ray of this element. The corresponding radial element of the anal fin may also suport additional rays, as may the last element of both the dorsal and anal fins. In all these instances the explanation previously given in the case of *Amia* and *Lepidosteus* holds good. It is possible in those genera (e. g. *Citharinus*) where the first radial element of the dorsal fin possesses supernumerary rays or spines, and there are also vestigial elements anterior to it, that the additional rays pertain to certain of the hinder vestigial elements.

The mode of articulation of the dermal fin-rays with their supporting radial elements is subject to a wide range of variation in different Teleosts, and even in different portions of the same fin. The more characteristic articulations are, for the most part, well known to ichthyologists; but it is nevertheless worth while to summarize the part played by the different segments of the radial elements in their formation. Briefly, it may be said that the method of articulation is dependent upon (1) the *size* of the dermal fin-rays; (2) the extent and kind of movement which takes place between the rays and the radial elements; and (3) variations in the method by which similar results are produced in different groups of Fishes.

The simplest, and probably the more primitive method, occurs in such instances where, as in *Amia* and *Lepidosteus, Osteoglossum* and *Muræna*, the cleft base of each fin-ray merely embraces or clips the distal segment of its radial element. This method is characteristic of the soft multiarticulate variety of fin-ray, and is sometimes to be found throughout the whole extent

of a fin, not only in the genera above mentioned, but in the Pleuronectidæ, Gymnotidæ, Lophobranchii, and Plectognathi, and very generally also in the feebler rays which constitute the hinder part of the fin in such Teleosts as possess a distal series of radial segments. With an increase in the size of the soft fin-rays towards the central and anterior portions of a fin, the proximal extremities of the cleft base of a ray may become enlarged and terminate in two lateral basal condyles which acquire a definite articulation with facets on the anterior portion of the distal end of the next succeeding proximal segment, in addition to its normal relations with its own distal radial segment; while it may not infrequently be the case that a firmer connexion between the distal segment and its fin-ray is brought about, by the development of two in-growing tubercular or peg-like processes from the inner surfaces of the cleft base of a ray, which fit into corresponding sockets on the lateral surfaces of the distal segment (peg-and-socket joint), as, for example, in *Citharinus* and *Conger*. In the case of the spinose and often massive rays of the anterior portion of a fin, the methods of articulation are many and various. Excluding the Acanthopterygii and dealing first with the Physostomi, the base of a spine, by the secondary closure of the basal cleft, may become converted into a transversely extended condyle articulating, in the absence of a distal segment, with a suitably modified surface or groove on the distal extremity of the proximal radial segment, and, in addition, possessing also a "hook-link" or even a "chain-link" connexion with the same segment, as is the case, for example, with the defensive spines of many Siluridæ; or the spines, retaining their cleft bases, may simply clip the dorsal margin of the segment (*e. g.* the guard-spines of the Siluridæ); or, finally, their method of articulation may be precisely similar to that of the larger soft rays, as in the serrated defensive spines of *Cyprinus* and *Barbus*.

The most characteristic methods of connexion between the spinose rays and their radial elements are, however, the "chain-link" and "hook-link" articulations of the anterior dorsal fin of the Acanthopterygii.

"Chain-link" articulations may be formed in several ways:—

(*a*) By the formation of a hook-like bony process from the hinder margin of a distal radial segment, which extends backwards to a sutural or a firm ligamentous connexion with a bony tubercle on the distal end of the next succeeding proximal segment, the bony loop thus formed traversing a foramen in the

base of the spinose ray. As previously mentioned in the case of *Conger*, *Citharinus*, and *Holocentrum*, the hook-like process probably owes its formation to a further modification of the "peg-and-socket" method of articulation. Examples of this form of "chain-link" articulation are to be found in the Scombridæ, Percidæ, Berycidæ, and Sparidæ.

(*b*) The suppression of the series of mesial and distal segments and the extension of the bony tubercle already mentioned above in the form of a loop forwards and downwards to its fusion with the distal end of the same proximal segment at a point more anterior to its origin—the loop, as before, traversing a foramen in the base of the spine. In this case there can be little doubt that the loop owes its formation to the growth of the bony tubercle by the ossification of the interossicular ligament. The Mugilidæ and the Labridæ furnish examples of this variety of "chain-link."

(*c*) The ingrowth of tubercles from the inner surfaces of the basal halves of a cleft spine through the distal margin of a proximal segment and their subsequent mesial union. This method is probably due to a modification of the "peg-and-socket" joint, except that the ingrowing tubercles perforate the superior margin of a proximal radial segment instead of a distal segment. Examples of this method of articulation may be found in the anterior and usually supernumerary spinose rays of the dorsal or anal fins of the Percidæ (*Mesoprion*), Sparidæ (*Pagellus*), Scombridæ (*Scomber*), Carangidæ (*Caranx*), and Mugilidæ (*Mugil*). It is possible, however, in some cases, as in the particular instance of the second and third anal spines of *Holocentrum*, that the ossification of the interossicular ligament, by which the distal radial segments are connected with their own and with immediately adjacent proximal segments, may contribute to the formation of the bony loops.

The "hook-link" is, so to speak, an incipient stage in development of a form of chain-link (*b*), and is associated with the suppression of both the mesial and radial segments and the growth of the bony tubercle above mentioned in the form of a hook through a foramen in the base of a fin-ray, but without again uniting with the proximal segment to which it belongs. In this form of joint, as previously pointed out, each ray or spine is solely supported by the proximal radial segment immediately posterior to that to which it rightly pertains, as, for example, in the dorsal fin of the Blenniidæ.

In the Sphyrænidæ and the Cottidæ may be found examples of peculiar methods of articulation which are different from any of those hitherto considered. In the former of the two families the distal radial segments have no hook-like processes, and the base of each spine forms a transversely elongated condyle which fits into a corresponding groove between the distal segment of one radial element and the adjacent distal end of the next succeeding proximal segment. The latter family exhibit a somewhat similar method of articulation, except that in the absence of distal segments the hinder margin of a postero-superior process forms the anterior boundary of the articular groove for reception of the condylar base of the spinose fin-ray.

From what has been said as to the articular relations of the fin-rays and their supporting radial elements, it is obvious that the development of spinose rays in Teleosts is one of the factors concerned in the reduction of typically trisegmental elements to the bisegmental or unisegmental condition. The existence of trisegmental elements is always associated with the support of soft multiarticulate rays, and there is not a single Teleost in which such elements support spines. And even where the majority of the elements are bisegmental, as in the anterior dorsal fin of the Siluroids, the development of special defensive or "guard-spines" is associated with the reduction of their supports to the unisegmental type. An increase even in the size of the soft rays is occasionally attended by a reduction from the trisegmental to the bisegmental condition, as may be seen in the anterior elements of the first dorsal fin in several of the Cyprinoids. It is, moreover, in the anterior spinose dorsal fin of the Acanthopterygian Teleosts that the reduction reaches its maximum, extending, as it does in whole families, to the existence of simple unisegmental elements. It is nevertheless certain that increase in the growth of spinose rays is not the only factor in this process of reduction. The Gymnotidæ have soft rays combined with unisegmental elements. The large anterior dorsal spines of the Percidæ, Berycidæ, and Sparidæ are supported by bisegmental elements, but the relatively much less massive spines of the Cottidæ and Mugilidæ by unisegmental elements. The development of spines may have been one of the factors in reduction, but there is also little doubt that the increasing specialization of existing Teleosts and the gradual loss of many of their more primitive characters are contributory causes.

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EXPLANATION OF THE PLATES.

[Unless otherwise stated the figures are natural size.]

Plate XXI.

Fig. 1. *Polyodon folium.* Radial elements of the dorsal fin.
2. *Amia calva.* Radial elements of the central portion of the dorsal fin.
3. *Lepidosteus osseus.* Radial elements of dorsal fin.
4. *Polypterus bichir.* Two radial elements, with their finlets and spines, from anterior part of dorsal fin.
5. „ „ Two similar radial elements from posterior part of dorsal fin (supra-caudal fin).
6. „ „ Radial elements of anal fin.
7. *Osteoglossum formosum.* Five radial elements from central portion of dorsal fin, with four fin-rays. Twice natural size.
8. „ „ Four radial elements of anal fin and four fin-rays. Twice nat. size.
9. *Conger conger.* Four radial elements of dorsal fin.
10. „ „ Distal radial segment and its "peg-and-socket" articulation with a fin-ray.
11. *Esox lucius.* Radial elements of dorsal fin and their fin-rays.
12. *Barbus vulgaris.* Radial elements of dorsal fin and fin-rays.
13. „ „ Radial elements of anal fin and fin-rays.
14. *Platystoma tigrinum.* Radial elements of dorsal fin and their fin-rays.
15. „ „ Dorsal view of anterior radial elements.
16. „ „ Four radial elements of anal fin.
17. *Citharinus Geoffroyi.* First four radial elements of dorsal fin.
18. „ „ Dorsal view of first three radial elements, showing mode of articulation of fin-rays with distal radial segment. Twice nat. size.

Plate XXII.

Fig. 19. *Gymnotus electricus.* Four radial elements of anal fin.
20. *Pleuronectes platessa.* Five radial elements of dorsal fin.
21. *Holocentrum spiniferosum.* The first four and the last eighteeen radial elements of the dorsal fin.
22. „ „ Dorsal view of four radial elements from anterior section of dorsal fin, to show mode of formation of the "chain-link" articulation and the dorsal groove.
23. „ „ Radial elements of anal fin.
24. *Mesoprion gembra.* The first four radial elements of the dorsal fin.
25. „ „ Three radial elements from the non-spinose posterior section of the dorsal fin.

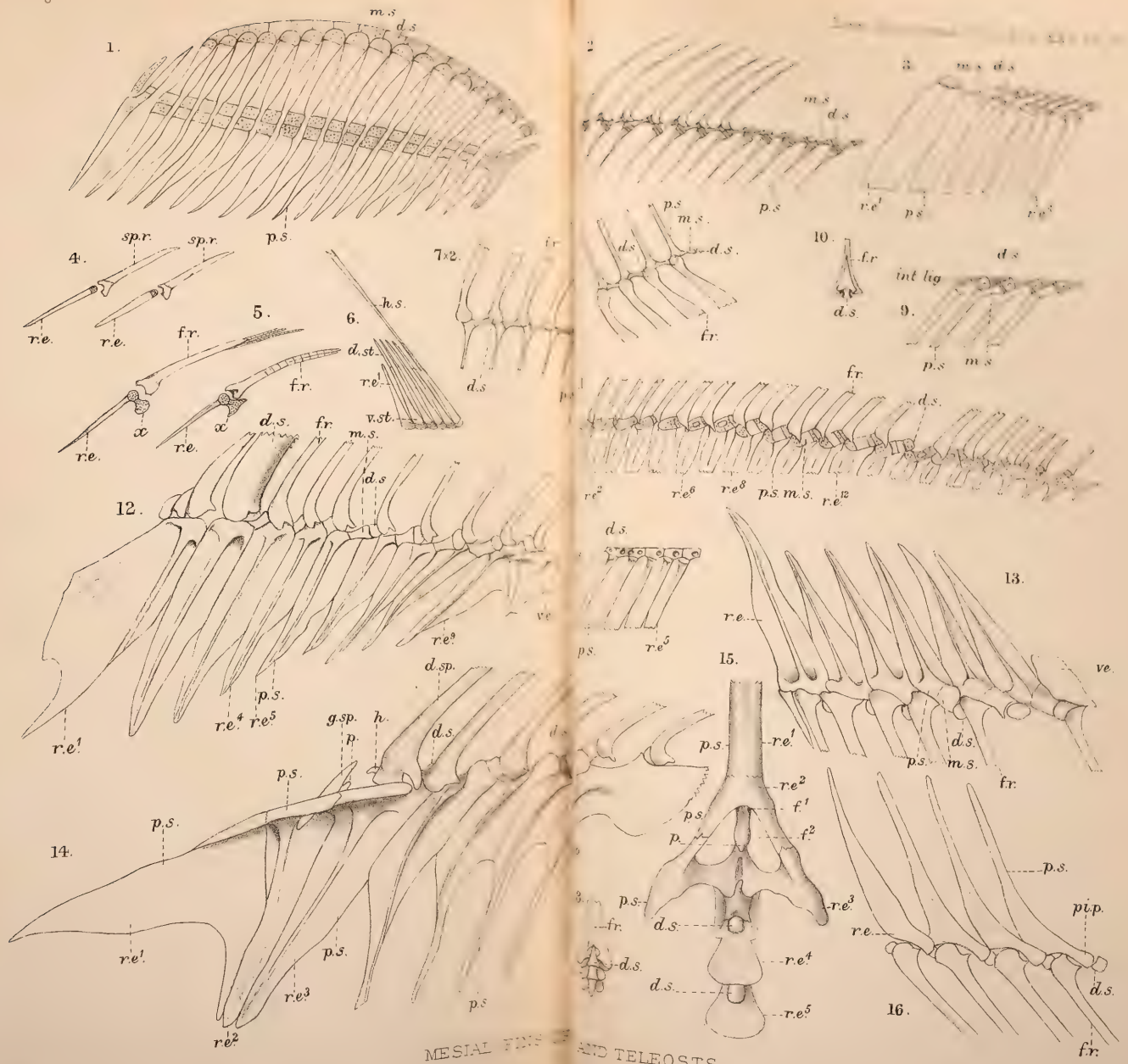
Plate XXIII.

Fig. 26. *Mesoprion gembra.* First four radial elements of anal fin.
27. *Sphyræna Commersonii.* Six radial elements of anterior dorsal fin.
28. „ „ Dorsal view of three elements from the same fin, and one spinose ray.
29. *Trigla gurnardus.* Dorsal view of four radial elements from anterior spinose portion of dorsal fin.
30. *Mugil capito.* Four radial elements of anterior dorsal fin.
31. *Anarrhichas lupus.* Four elements from dorsal fin and one fin-ray.
32. „ „ Four radial elements from anal fin. Half nat. size.
33. *Pseudoscarus superbus.* The sixth to the eleventh (inclusive) radial elements of the dorsal fin.
34. *Balistes capriscus.* Radial elements from the central portion of the posterior dorsal fin. Enlarged.
35. *Tetrodon immaculatus.* Radial elements of dorsal fin.
36. „ „ Radial elements of anal fin.
37. *Diodon hystrix.* Radial elements of dorsal fin.
38. „ „ Vertical section of a radial element and its fin-ray, to show the relations of a fin-ray to its distal radial segment, and the mode of articulation between the distal and proximal segments.

Reference Letters.

d.s. Distal segment of a radial element.
d.sp. Defensive spine.
d.st. Dorsal radial segment (anal fin of *Polypterus*).
f. Foramen for the passage of the muscles of fin-rays.
fc. Articular facet.
f.r. Fin-ray.
g.sp. Guard-spine.
h. Hook-like process.
h.s. Hæmal spine.
int.lig. Interossicular ligament.
n. Notch for passage of muscles of fin-rays.
m.s. Mesial segment of a radial element.
p.s. Proximal segment of a radial element.
pi.p. Postero-inferior process.
ps.p. Postero-superior process.
r.e. Radial element.
$r.e.^1$, $r.e.^2$, and so on. First, second, and other radial elements.
sp.r. Spinose ray.
v.e. Vestigial radial element.
v.st. Ventral radial segment (anal fin of *Polypterus*).

[The reference letters are uniform throughout.]



MESIAL FINS OF TELEOSTS.

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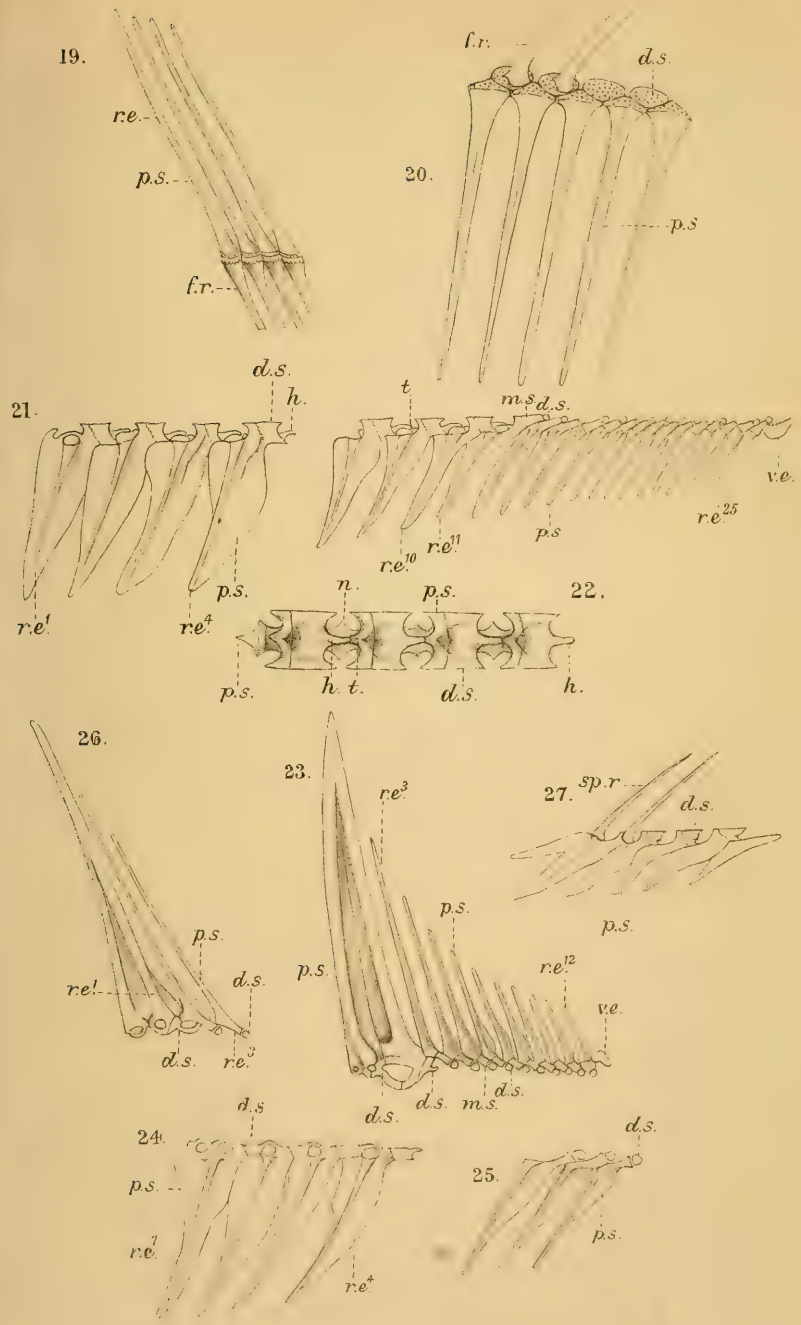

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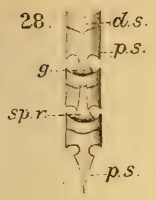
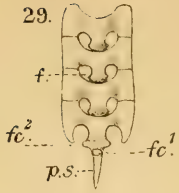
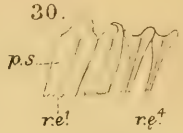
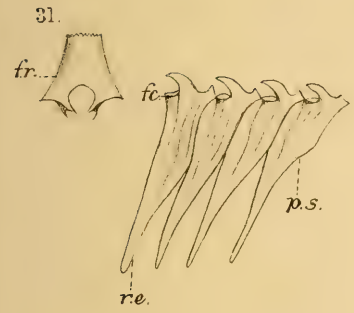
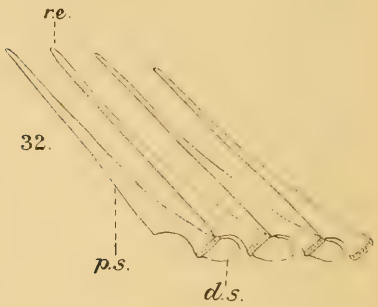
MESIAL FINS OF GANOIDS AND TELEOSTS.

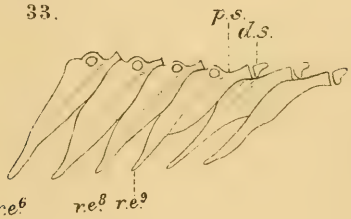


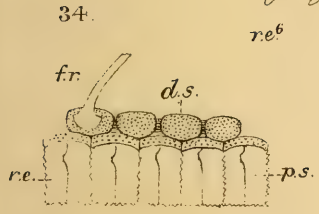


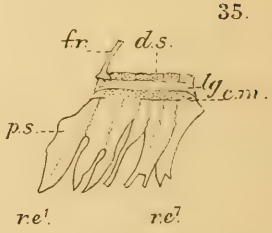


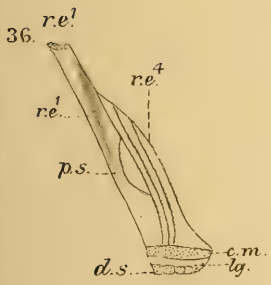


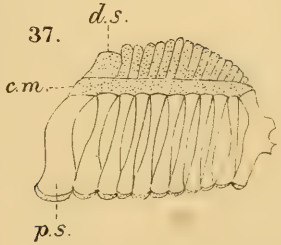


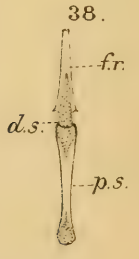












F.W. Crispe del. ad nat.
F.H. Michael lith.

Mintern Bros. imp.

MESIAL FINS OF GANOIDS AND TELEOSTS.